PEN REARING AND IMPRINTING OF FALL CHINOOK SALMON

ANNUAL REPORT

1987

by

William R. Nelson, Project Leader
Jerry F. Novotny, Thomas L. Macy
Michael P. Faler, and John W. Beeman
U.S. Fish and Wildlife Service
Seattle National Fishery Research Center
Willard Field Station
Cook, Washington 98605

and

Curtis L. Burley, Project Leader
Vancouver Fisheries Assistance Office
9317 Highway 99, Suite I
Vancouver, Washington 98665

Prepared for

Jeffrey C. Gislason, Project Manager
U.S. Department of Energy
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ABSTRACT

The 1987 field season was the third and final year fox the rearing and release of juvenile upriver bright chinook salmon (Oncorhynchus tshawytscha) at off-station sites. Disease problems in the hatchery where fish for the study were spawned and hatched resulted in the movement of trials to Drano Lake, a backwater located near river km 261, 105 km downstream of Rock Creek and 205 km downstream of Social Security Pond, the two off-station rearing sites where studies were completed in 1984-86.

Fish in fed treatments were successfully reared in pens during March, April, and May and were released in the third week of May at a mean size of about 4,5 g (lOO/lb). Growth and physiological development of fish reared In Drano Lake were only slightly faster than observed in hatchery controls over much of the rearing period. However, during the final two weeks of rearing, ATPase activities and growth of the fish reared. in pens increased, and at release the fed treatments tested in Drsno Lake were significantly larger, and physiological development was significantly ahead of hatchery controls.

The health and condition of fed fish in Drano Lake remained good throughout the study and survival was high (>99%) in all treatments; no pathogens were detected in any of the groups. However, infectious hematopoietic necrosis was diagnosed among upriver brights being reared in the hatchery; the latter group was destroyed on May 21.

Unfed fish grew poorly throughout the rearing period with little or no detectable growth in the two higher density treatments and mean growth of less than 0.3 g in the lower density. Survival of fish reared at the higher density was poor, while survival in the two lower density treatments was much better.

Densities tested in pen rearing trials have been much lower than the maximum recommended in terms of available rearing spare. However, during periods of limited water exchange the highest density tested so fax (4.13 kg/ma) would be above the recommended maximum for the rearing conditions encountered In the off-station rearing sites.

Costs of rearing fish are dramatically affected by densities. Alternate rearing facilities, including polyethylene and wooden walkway framing, are initially a higher investment, but may prove to be *more* desirable than the aluminum frames tested during this study.

INTRODUCTION

Fall chinook salmon (_Oncorhynchus tshawytscha)_ have been reared in lower Columbia River hatcheries as a mitigation measure to compensate for inundated spawning and nursery habitat since the construction and flooding of John Day Reservoir. However, these fish have normally returned to the fishery in the lower river, or to the hatcheries of Origin and have not entered the areas in the Columbia River system for which the mitigation measures were intended. Therefore, in 1983, the U. S. Fish and Wildlife Service entered into an agreement with the Bonneville Power Administration to evaluate rearing upriver bright fall chinook salmon in temporary rearing facilities installed in backwaters and adjacent ponds along the Columbia River, between John Day and Priest Rapids 'dams. Fish reared and acclimated at sites along this stretch of the mid-Columbia River would then return to the release sites rather than to the hatcheries of origin in the lower river.

During the first year of the study, 1983, potential study sites between Priest Rapids Dam and John Day Dam were evaluated in terms of accessibility, physical characteristics (depth, water source and exchange, size etc.), and location (Novotny et al. 1984). Various rearing scenarios were subsequently tested in net pens installed in the two study sites selected--a pond adjacent to the Columbia River Social Security Pond (river km 468), and a backwater, Rock Creek (river km 367)--in 1984, 1985, and 1986 (Novotny et al. 1985; 1986a; 1986b). In addition, a barrier net was constructed at Rock Creek to simulate a low-care backwater rearing scenario during three years of rearing, 1984-86. Control groups of juvenile fish were reared in the hatchery during all years as a means of comparing off-station rearing success and return of adults with that of the hatchery.

Plans to rear fish at Rock Creek and Social Security Pond in 1987 were abandoned when it was learned that the upriver bright stock spawned at the Little White Salmon National Fish Hatchery (LWSNFH) had been exposed to infectious hematopoietic necrosis (IHN) during the initial stages of rearing. Agencies concerned with the management of upriver stocks (Oregon Dept. of Fish and Wildlife, Washington Dept. of Fisheries, U. S. Fish and Wildlife Service, and Columbia River Intertribal Fish Commission) jointly concluded that the risk of transferring potentially-infected fish to the upriver rearing sites 'was' too great and contrary to disease policy.

Therefore, an alternative plan was developed which called for the rearing of fish in net pens in Drano Lake, the receiving body of water for the effluent releases of the LWSNFH. This strategy allowed for the continued testing of various rearing densities and the comparison of hatchery controls with pen-reared fish. The entire study p&an originally intended fox Rock Creek` was essentially transferred to Drano Lake, including all net pen rearing, with the exclusion of the installation of a barrier net.

Additional disease problems developed at LWSNFH with the diagnosis of IHN in upriver brights in the hatchery raceways, including those being monitored as controls for this study. The control fish were subsequently destroyed along with the entire upriver bright production in the hatchery. IHN was not diagnosed in any of the groups reared off-station, therefore, they were released as planned.

METHODS

Water Quality and Zooplankton

Water temperatures were recorded daily at one meter below the surface, and weekly at one-meter intervals from the surface to the bottom. Dissolved oxygen profiles were monitored weekly in, or near the net pens. Alkalinity, nitrate/nitrite, orthophosphate, total organic carbon, total iron, total manganese, and ammonia were monitored near the beginning, mid-point and conclusion of rearing in Drano Lake, These water quality samples were transferred to a private consultant for analysis. Secchi disk, pH, and conductivity readings were recorded periodically during rearing.

Zooplankton densities were monitored weekly by sampling a vertical profile of the water column in the area where the pens were located using a Wisconsin net.

Fish Rearing

Adult upriver brights were captured by the Oregon Dept. of Fish and Wildlife at the Bonneville Hatchery and the Bonneville Dam fish ladder during September and transferred to LWSWH for spawning in December. Hatching and initial rearing was completed at LWSNFH.

Equipment for rearing fish in Drano Lake was transferred from Rock Creek and Social Security Pond during the first two weeks of March after the proposal to move the study was evaluated and approved by all concerned parties. Drano Lake is an 85.8-hectare (212-acre) backwater located near river kilometer 262 (river mile 163) on the Washington side of the Columbia River. The outlet is a 100-meter opening (approximately 300 feet) to the main river, making water: level fluctuations (commonly 1.0-1.5 m overnight) in the backwater subject, to the water level elevation changes in the Bonnevills pool. Pens were anchored along the north shore of the backwater in water ranging in depth from 6-8 m (20-30 feet), depending on water level elevations in the Bonneville pool.

Fish were stocked in net pens (6,lm x 6.lm x 2.1m with 3.2mm mesh netting) during the second and third weeks of March at a size of ,58-.62 g (730-760/lb) and were reared in pens during the subsequent three-four weeks, prior to coded wire tagging. During this period fish were fed a 34% body weight/day ration of Biodiet.

Coded wire tagging (cwt) was completed on site from April 1 to 15; as fish were tagged, they were distributed among the various treatments and transferred to pens with 4.8-mm mesh (Appendix 1) . Size of fish at the time of distribution varied from about 0.9-1.1 g~ (415-500/lb) depending on when, the fish were tagged. Fish were started on a ration of Abernathy Dry at a rate of 3-4% body weight/day soon after stocking In the various treatments.

Treatments tested In 1987 included the testing of various densities of fed and unfed groups in net pens,. Among ~nd treatments, four cwt groups of about 50,000 fish/group were stocked in twelve pens at "regular" density--.2,6 kg/m3 (.016 lb/ft3), with a mean number of 18,340 fish/pen; two owt,groups of about 37,200 fis,h/pen wene stocked in two pens at "double 11 density-.52 kiff/ma (.,032,lb,/ft3); two cwt groups of about 55,000 fisb/pen were, stocked In two pens at "triple" density--.78 kg/M.3 (.0,48 lb/ft3); and two cwt groups of about 75,000 fish/pen were. stocked in two pens at "quadruple" density--.87 kg/m3 (.053 lb/ft3).

Densities teated i.n fed treatments in pens were compared with maximum recommended loading densities used in hatcheries (based on surviva-1 to adult) using three methods; 1) a spatial

index, which is an expression of weight of fish per unit volume of rearing space (Piper 1970); 2) a density Indsx-j which is,

the ratio of weight of fish per unit volume to the mean length of the fish In the rearing enclosure (Piper et al. 1982); and 3) a

flow index, which relates weight of fish per unit volume of rearing space, to rate of water exchange through the rearing facility (Piper et al. 1982).

Fish sizes were standardizer to a stocking size of 2.0 g and a release size of 4.5 g for purposes of comparing densities among the various treatments. In practice,, sizes of fish at release in some of the treatments may have been somewhat smaller than the 4.5 g-fish used in calculating estimates for density comparisons. Therefore, in *some cases,* expressions of density of fish In pens in Drano Lake were slightly different than standardized release estimates.

In unfed groups, two pens each were stocked at low density--991 fish/pen, .013 kg/m3 (.001 lb/ft3); two were stocked at medium density--1,982 fish/pen, .025 kg/m3 (.002 lb/ft3); and two were stocked at high density--3,964 fish/pen .051 km/m3 (.003 lb/ft3). Unfed fish were not cwt.

Three methods were used to inventory growth using weight change per two-week interval: 1) the standard hatchery practice of weighing several pounds of fish live, counting them, and calculating a number of fish/pound estimate; 2) perservation of 30-50 fish from each pen in 10 % formalin and subsequently weighing them in the laboratory (to which a preserved/live regression was developed and applied--Appendix 2); and 3) the recording of individual weights of live fish sampled *from* each treatment every two-weeks. Estimates of growth using these throe methods varied (Appendix 3), therefore converted preserved weights were combined with individual live weights for monitoring growth among various treatments.

Feeding rates were maintained at the prescribed 3-4% body weight/day feeding ration throughout the rearing period. Growth was compared among all groups of fish monitored, including the hatchery, by applying a one-way, or a one-way nested, analysis of variance and a Newman-Keuls multiple range test (Zar 1984) to changes in fork lengths over the searing period.

An abbreviated record of field work completed in 1987 has been included in a chronology of significant events In Appendix 4. A review of previous annual reports of pen rearing activities provides additional method and location descriptions, as well as a summarization of past field activities and results (Novotny et al. 1984; 1985; 1986a; 1986b).

Fish Physiology

Smoltification was monitored using Na-K gill ATPase activity as the primary indicator. Fish were collected live in the field from net pens and from LWSNFH raceways and transferred to the laboratory where gills were clipped, fixed, and frozen according to the methods of Zaugg (1982); normally, 10 fish were sampled biweekly from each treatment. In addition, blood plasma thyroxine (T4) levels were similarly monitored throughout the period of rearing. Blood serum samples were frozen and transferred to the Oregon, Cooperative Fishery Research Unit for analysis according to methods developed by Folmar end Dickoff

(1981).

One 24-h seawater challenge trial was completed using fish from regular and quadruple densities at the conclusion of the rearing period. The seawater challenge is commonly used as an indication of the readiness of smolts to enter the ocean. If the fish are able to regulate blood-sodium levels below 170 mmol/l they are considered smolted, if not, they are not ready for ocean entry (Wedemeyer et al. 1981).

Differences in blood-sodium levels between regular and quadruple density treatments were tested in the absence of a comparison between fish reared in the hatchery and those reared off-station. Fish reared as oontrols in the hatchery were destroyed prior to the seawater challenge trials, therefore no fish were available for comparison, Procedures used in the seawater challenge were the same as used in previous years (Novotny et al. 1986a; 1986b).

Blood plasma cortisol levels were monitored for signs of stress at transfer from the hatchery, one day after transfer, and one week after transfer. cortisol was also monitored around cwt dates, including one day before, one day after, and one week after tagging. Samples were analyzed at the Oregon Cooperative Fishery Research Unit using methods developed by Schreck (1982).

Routine health checks were completed on each of the off-station groups, as well as those monitored in the hatchery, during regular sampling of growth and physiological condition using the Utah fish quality indexing methods (Goede in press,).

These observations included simplified blood work-ups, examination of internal organs, and general evaluation of external characteristics. Fish in net pens were also examined by health officials at the Lower columbia Fish Health Center, Cook, Washington, every other week, or more often, au requested by health officials.

Rearing Costs

Expenses of net pen facilities used during the present study as well as for other available net pen facilities, were compared using quotes from current (1987) costs. Hatchery efficiency ratios (Senn et al. 1984) calculated In previous reports were updated using the more complete data set now available, and additional rearing scenarios were included.

Adult Recovery

Weirs were installed in Rock Creek (proper) and in the effluents (two locations) of Social Security Pond from the first weak of September through November. In addition, a Merwin trap net (1.6 cm bar mesh, 9 m x 46 m lead, and 9 m x 9 m wings) was emplaced at Rock Creek and fished throughout September, October, and November. Numbers of adult returns to the rearing sites were augmented with recovery information available from the Pacific Marine Fisheries Commission for releases of fish in 1984 and 1985.

RESULTS

Water Quality

Water temperatures in Drano Lake ranged between 6 C and 15 c but remained below 12 C throughout much of the rearing period (Fig. 1). Surface temperatures warmed quite rapidly to near 15 c during early *May,* but a cooling trend in air temperatures held the water temperatures between 12 C and 14 C over the remainder of the rearing period. In March and April, little difference was noted between surface and bottom temperatures. While surface temperatures in May and June increased, bottom temperatures remained near 9 C, or only slightly higher. The cooler temperatures near the bottom in Drano Lake were apparently influenced by the inflow of the Little White Salmon River, which averaged about 9 C over the rearing period.

Dissolved oxygen concentrations remained high throughout the water column in open water and in a high density pen which was monitored over the period of rearing for effects of high densities on oxygen demand (Table 1). Concentrations decreased over the rearing period in association with warming water temperature, but no effects due to the rearing of fish in Drano Lake we're observed. Secchi disks readings ranged from 1.5 *m to* 3.3 m, conductivities, from 49 to 105 micromhos/cm, and hydrogen ion concentrations, from 1.4 to 8.3 from early March, prior to stocking of fish, until June.

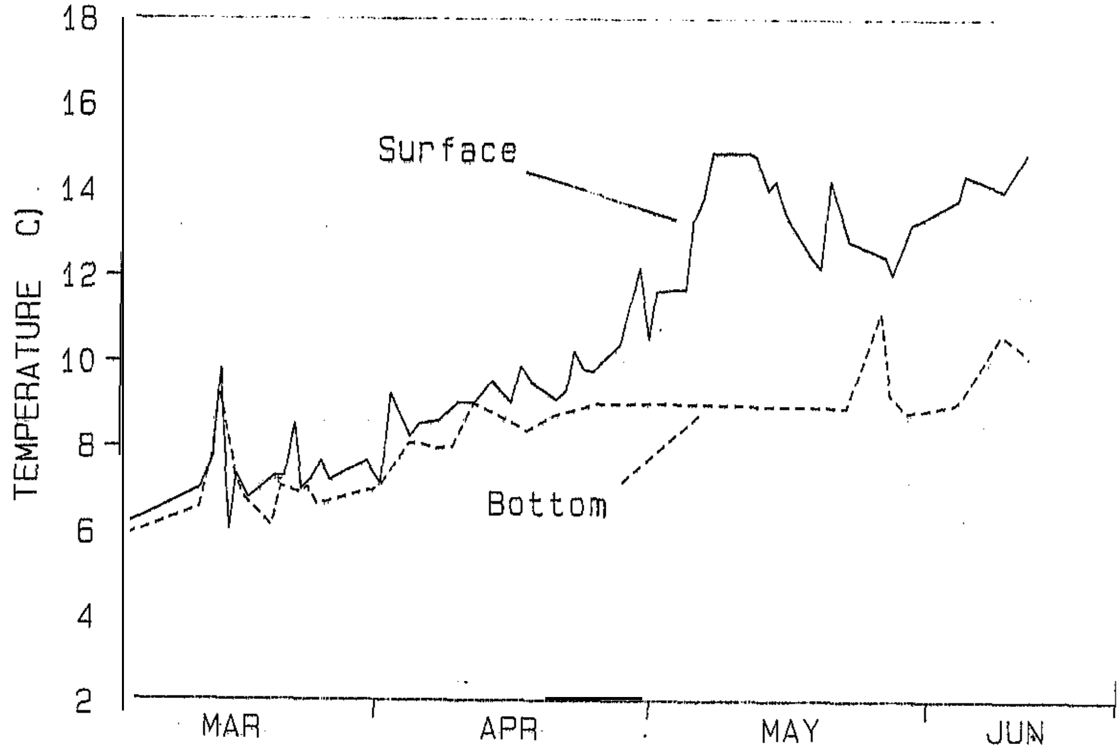


Figure 1. Surface and bottom temperatures in Drano Lake during the rearing period, 1987.

Table 1. Dissolved oxygen concentrations at the surface (S), 2, 4, and 6 meters in open water near the pens; at the surface (S) and near the bottom (B) of the net in a quadruple density pen; and mean Secchi disk, conductivity, and pH readings from surface to bottom, Drano Lake, 1987.

Parameter	Depth	Date											
		3/4	3/15&16	3/30	4/9	4/16	4/21	4/29	5/7	5/13&15	5/22	5/29	6/4
Dissolved Oxygen (open water)	S	12.8	12.4	12.8	11.3	10.8	10.6	10.1	10.5	10.0	10.1	10.1	8.6
	2	12.8	12.4	12.6	11.5	10.8	10.6	9.7	10.5	9.8	9.9	9.7	9.2
	4	12.7	12.3	12.6	11.6	11.8	10.6	9.8	10.5	9.8	9.6	9.6	9.8
	6	—	12.2	12.5	11.6	10.0	10.6	9.9	10.5	9.5	9.8	9.5	10.3
Dissolved Oxygen (in pen)	S	—	12.3	12.2	11.3	11.7	11.9	11.2	9.2	10.1	—	—	—
	B	—	12.0	12.0	10.5	11.4	12.0	11.9	10.3	10.4		—	—
Secchi Disk (m)	$\bar{X}$	—	1.5	—	3.3	1.9	2.4	2.2	2.4	2.1	1.5	1.6	1.9
Conductivity (micromhos/cm2)	$\bar{X}$	55	54	50	49	57	57	59	61	—	—	—	105
pH	$\bar{X}$	7.6	7.6	—	8.0	7.4	—	—	—	7.8	8.3	7.7	—

Drano Lake, in comparison to the upstream sites, had low alkalinities and low nutrient concentrations throughout the rearing period (Table 2). Iron, manganese, and un-ionized ammonia concentrations also reflected a low nutrient level; subsequent decomposition, and water circulation in Drano Lake prevented a build-up of food or waste from occurring. Ammonia concentrations sampled on May 7 within the pens containing fed fish were less than .05 mg/l (less than .02 mg/l un-ionized ammonia).

Fish Rearing

<u>Growth and Survival of Fad Fish</u>

Release sizes of fed fish (using fork length for comparison) among the four *treatments* tested in 1987 were *similar* in regular (72.03 mm), quadruple (71.13 mm), and triple densities (70.420 mm) (Table 3; Fig, 2). However, mean fork length of double density fish at release (73.84 mm) was significantly larger ($P<.05$) than either of the other high density treatments, and similar to mean length of fish reared at regular *density* (Table 4).

On the final day for which a valid comparison of off-station fish with hatchery fish was possible, May 11, fed fish In all treatments were significantly larger than control fish in the hatchery (Table 5). IHN was positively confirmed in the 'hatchery fish during the following days, and they were placed on a maintenance diet while decisiona about, and preparations for,

Table 2. Selected water quality parameters monitored at Drano Lake during 1987 (values expressed in mg/l).

Parameter	March 19	May 7	May 22
Buffering Capacity			
Alkalinity as $CaCO_3$	22	31	28
Nutrients			
Nitrate/Nitrite-N	.05	<.05	.09
Orthophosphate-P	.019	.008	.008
Organic Carbon (total)	2.8	1.2	1.6
Indicators of Poor Water Quality			
Iron (total)	.15	.16	.10
Manganese (total)	.044	.005	.008
Ammonia as N (un-ionized)	<.02	<.02	<.02

Table 3. Stocking and release summaries of fed fish reared at regular, double, triple, and quadruple densities, Drano Lake, 1987.

Treatment Summaries	Stocking	Release	Difference
Regular			
Number	18,341	18,103	238(51)a
Number/pound	413	107	306
Mean Weight (g)	1.10	4.23	3.13
Pounds/ft3 (kg/m3)	.016(.26)	.060(.98)	.044(.72)
Total Weight in Pounds (kg)	44.4(20.2)	168.7(76.6)	123.4(56.4)
Rearing Period (days)	April 12-15	May 21	33-36
Double			
Number	37,206	36,826	380(152)a
Number/pound	413	101	312
Mean Weight (g)	1.10	4.48	3.38
Pounds/ft3 (kg/m3)	.032(.52)	.130(2.11)	.098(1.59)
Total Weight in Pounds (kg)	90.1(40.9)	363.4(165)	273.3(124.1)
Rearing Period (days)	April 11	May 21	40
Triple			
Number	55,130	54,380	749(444)a
Number/pound	430	110	320
Mean Weight (g)	1.05	4.12	3.07
Pounds/ft3 (kg/m3)	.048(.78)	.176(2.87)	.128(2.09)
Total Weight in Pounds (kg)	133.6(60.6)	493.5(224)	359.9(163.4)
Rearing Period (days)	April 8 & 9	May 22	42-43
Quadruple			
Number	75,202	74,358	843(467)a
Number/pound	504	105	399
Mean Weight (g)	0.9	4.34	3.44
Pounds/ft3 (kg/m3)	.053(.87)	.254(4.13)	.201(3.26)
Total Weight in Pounds (kg)	149.0(67.7)	710.8(322.7)	561.8(255)
Rearing Period (days)	April 2-4	May 22	40-42

a/ Difference includes both natural mortality and samples collected for physiological testing. Parentheses indicate mean number of each group lost to natural causes.

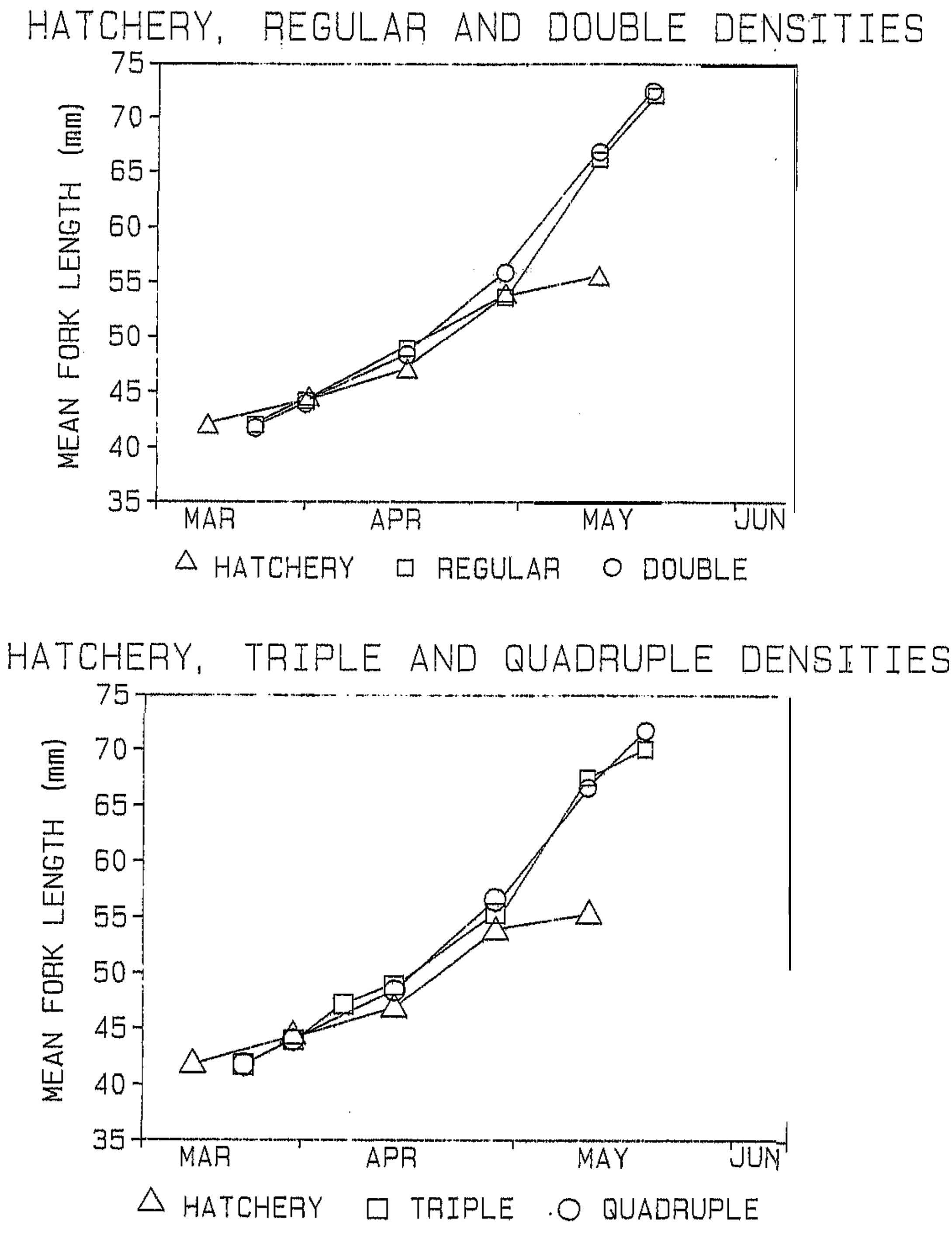


Figure 2. Mean lengths of fed fish reared at regular (1x), double (2x), triple (3x), and quadruple (4x) densities in Drano Lake, and of control groups of fish reared at the Little White Salmon National Fish Hatchery, 1987.

Table 4. Summary of a nested one-way analysis of variance and a Newman-Keuls multiple-range test comparing size of fed fish using fork lengths in regular (1x), double (2x), triple (3x), and quadruple (4x) densities on the release date--May 21-23. Treatments with the same grouping letter are not significantly different at the .05 level.

Summary of nested one-way ANOVA (P=.05):

Dependent Variable	Source	D.F.	ANOVA S.S.	f-Value	P>f
Fork Length	Density	3	393.31	3.18	0.0235
	Pen(density)	14	1884.47	3.27	0.0001

Summary of multiple-range test:

Variable	Density	Mean Value	N	Grouping
Fork Length	2x	73.84	59	A
	1x	72.03	392	AB
	4x	71.13	60	B
	3x	70.42	59	B

Table 5. Summary of a one-way analysis of variance (ANOVA) and a Newman-Keuls multiple range test comparing size of fed fish using fork lengths from all treatments tested in Drano Lake, and from control groups reared in the Little White Salmon National Fish Hatchery (LWSNFH) on May 11, 12, and 13, 1987. Treatments with the same grouping number are not significantly different at the .05 level.

Summary of one-way ANOVA (P=.05):

Dependent Variable	Source	D.F.	ANOVA S.S.	f-Value	P>f
Fork Length	Treatment	4	5040.51	59.53	0.0001

Summary of multiple-range test:

Variable	Treatment	Mean Value	N	Grouping
Fork Length	3x	67.80	45	A
	2x	66.96	46	A
	4x	66.92	50	A
	1x	66.23	43	A
	LWSNFH	55.02	43	B

their disposal on May 20 and 21 were being finalized, Therefore, neither growth nor physiology of the control fish, was monitored after May 11.

Size of hatcher; controls had been smaller than the size of fish reared off-station until two weeks prior to the final sampling date (Fig 2). Mean fork length of control fish monitored in the raceway at LWSNFH increased only slightly during the final two weeks, from 63.50 mm to 55.02 mm, while mean weight increased from 1.57 g (285/1b) to 1.77 g (255/lb).

Mean weights of fish at release were 4.23 g (107/lb), 4.40 g (101/lb), 4.12 g (110/lb), and 4.34 g (105/lb), for regular, double, triple and guadruple treatments respectively (Table 3). Weights were not compared statistically because of the large amount of variation associated with weights of small fish and feeding periods--fish that had just fed would be larger when sampled than those of the same size, but which had not fed. Total mean weight gain/fish ranged from 3.07 g at triple density to 8.44 g at quadruple density.

Rearing periods differed somewhat because of the on-site tagging and distribution, lasting 33-36 days, 40 days, 42-43 days, and 40-42 days for regular, double, triple, and quadruple densities, respectively (Table 3). Total weight of fish produced per pen during the rearing period in Drano Lake in each treatment was as follows: regular density-56.4 kg, double density-124.1 kg, triple density-163.4 kg, and quadruple density-256.0 kg. Total food fed ranged from a mean of 251 kg in regular treatments to 1206 kg in quadruple treatments, over the 33-43 days of rearing.

Survival among fed fish was good, with an average mortality of less than 1% in all treatments; mortality was slightly higher in the highest density treatments (Table 3). Significant losses did not occur during any two-week period, but losses toward the beginning of the rearing period and toward the end appeared to be somewhat higher (Appendix 5).

The entire group of upriver brights reared at LWSNPH were destroyed after increased *mortalities,* noted in several of the raceways on April 21, were diagnosed and confirmed on May 5 as being IHN. Fish reared in *net-pens* were closely monitored, especially after IHN was diagnosed among the hatchery stock used in stocking the pens. No pathogens were detected however, during routine observations in any of the fish reared off -station (Table 6). Fish monitored in the hatchery as a control were taken from a raceway which remained undiagnosed until the second week of May; total mortality in that particular raceway was never higher than 0.4 %

<u>Physiology of Fed Fish</u>

Gill Na-K ATP-ase activity remained low in all off-station treatments throughout the rearing period, ranging *from* around 11 micromoles Pi/mg Prot/hr (units of activity) at the beginning of the rearing period to between 15 and 20 units of activity at release (Fig 3). Differences among the four fed treatments were

Table 6. Summary of health inspections completed by the Lower Columbia River Fish Health Center, Drano Lake, 1987.

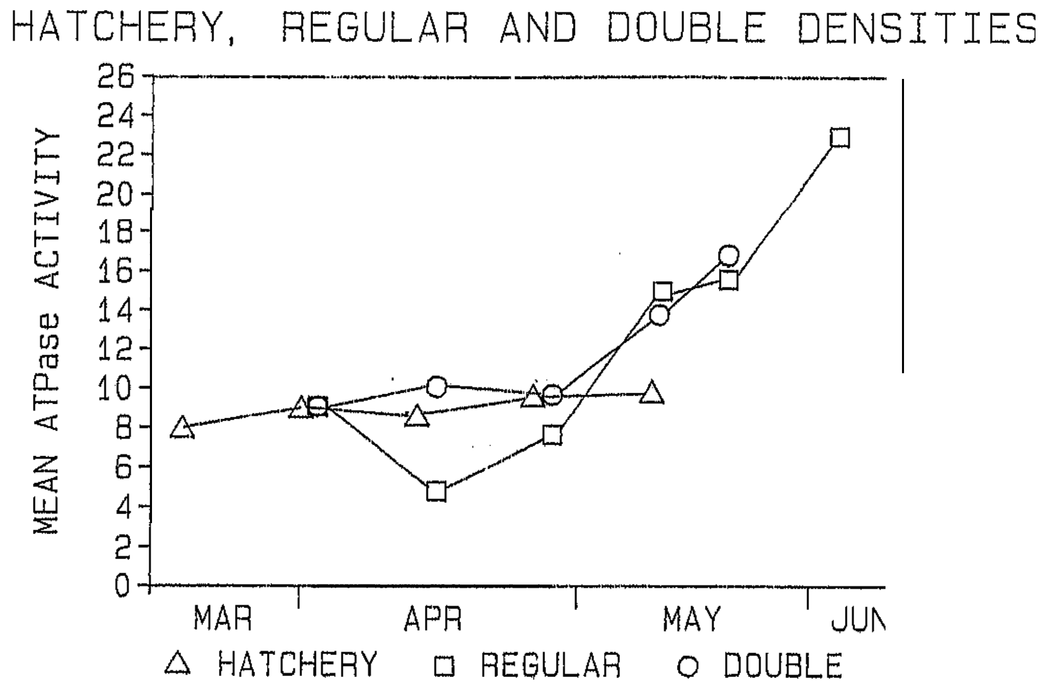
Date Sampled	Pen Number	Virus Exam	Bacterial Exam	Parasite Exam
Mar 25	Temporary 1-6	17	6	0
Apr 16	Pens 2-12; 19-24	34	7	34
Apr 29	Pens 1-12; 19-24	54	0	54
May 6	Pens 1-12; 19-24	54	0	54
May 7 & 8	Pens 1-12; 19-24	432	0	90
May 11	Pens 13-18	108	0	0
May 12	Pens 1-12; 19-24	54	0	54
June 2 & 3	Pens 8 & 13-18	23	3	53

Summary findings:

No major pathogens were found. _Ichthyophthirius_, _Scyphidia_, and _Epistylis_ were observed on skin and gills of some of the fish sampled on June 2 and 3.

Additional comments:

Fish held in the raceways at the Little White Salmon Hatchery were diagnosed IHN-positive on April 22 (increased mortalities had been noted as early as April 10). However, even though fish used in the net pen study were taken from the Little White Salmon Hatchery raceways, no virus isolations occurred on any of the samples examined from Drano Lake pens.



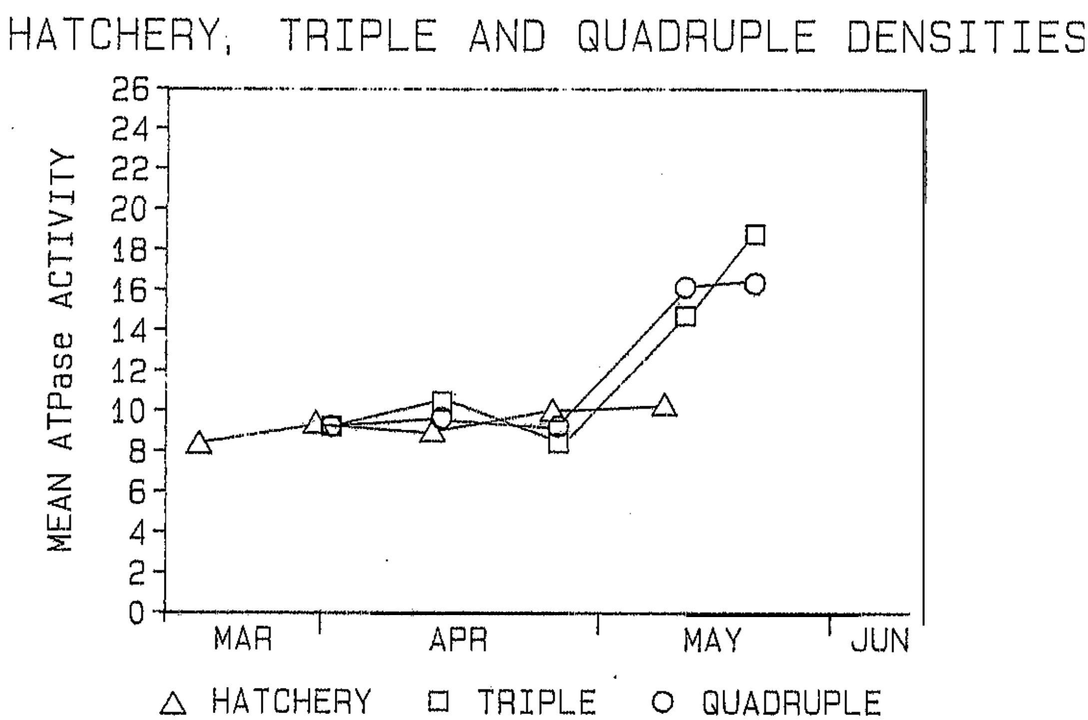


Figure 3. Mean ATPase values of fed fish reared at regular (1x), double (2x), triple (3x), and quadruple (4x) densities in Drano Lake, and of control groups of fish reared at the Little White Salmon National Fish Hatchery, 1987.

not significant at release (P>.O5)(Appendix 6). Hatchery control fish ATPase values remained very similar to those of off-station fish over the initial six weeks of comparison. However, on the final date of comparison (May ll), values for hatchery fish were significantly (P<.05) lower than in the treatments of fed fish reared off-station (Appendix 6),

Gill samples were collected from fish from all treatments as they passed through Bonneville Dam 7-9 days after release. Mean ATPase activity for the fish collected at the dam (treatments grouped because of the relatively few fish sampled--19) was 25.1 units of activity; mean size was 5.1 g (89/lb).

In addition, a group of 160 regular density fish was held in a net pen for two weeks after release of fed fish from other pens to monitor ATPase activity as water temperatures in Drano Lake warmed. ATPase activity in this group continued to increase, and reached 23 units of activity at release, June 2, 'even though water temperatures remained relatively cool, between 12 c and 14 C. Mean size of this group at release was 8.8 g (53/lb).

Blood serum thyroxine values of fed fish were similar to the values recorded in hatchery control fish during the initial comparisons in late March and early April (Fig.4). Thyroxine~ values of all fed groups were higher during the *remainder* of the rearing period than values observed 'in the hatchery fish. Peak concentrations among fed groups occurred earliest in quadruple densities and progressively later in triple, double, and regular densities. Peak concentrations of all fed fish ranged between

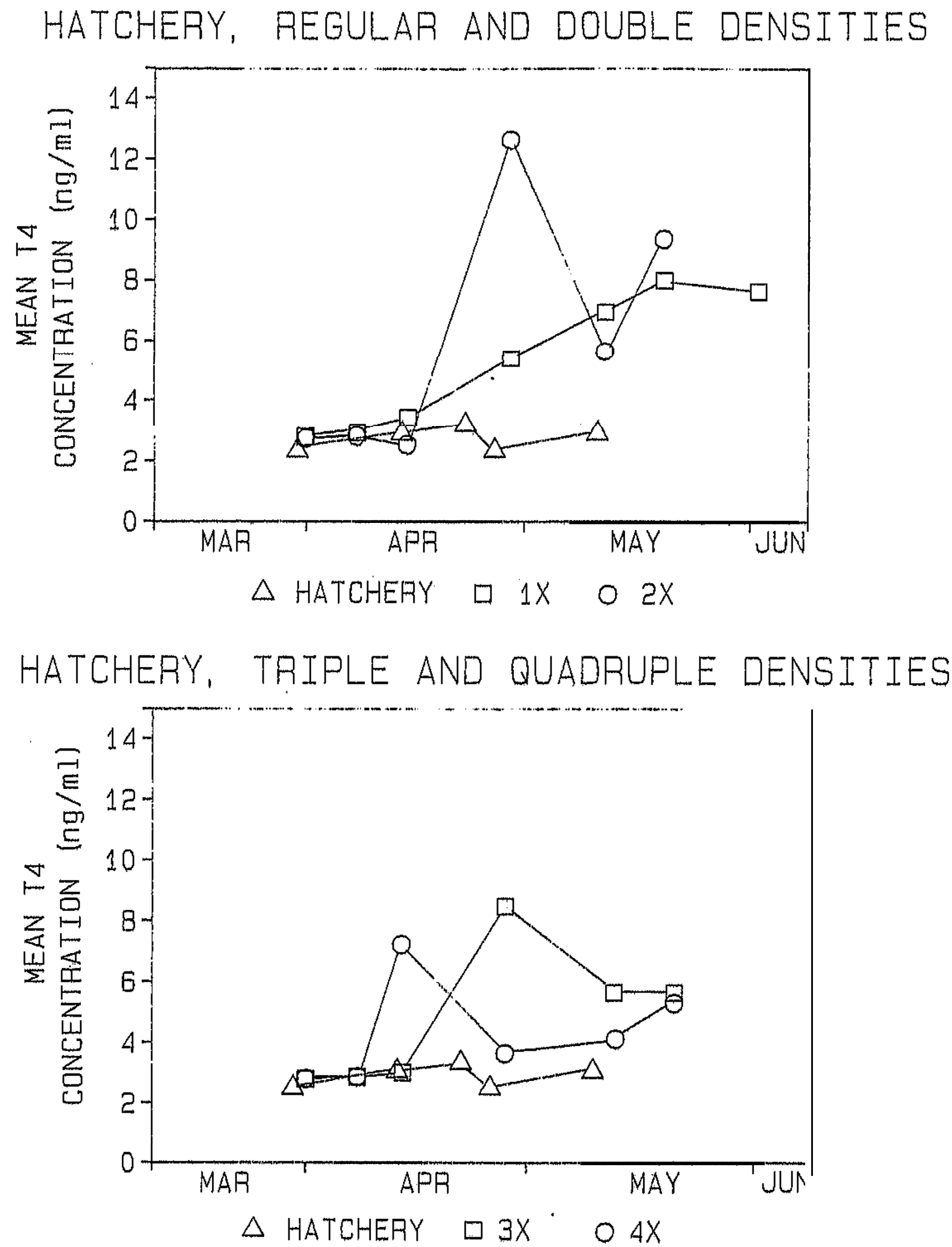


Figure 4. Blood serum thyroxine (T4) concentrations (ng/ml) of fed fish reared at regular (1x), double (2x), triple (3x), and quadruple (4x) densities in Drano Lake and of control groups reared at Little White Salmon National Fish Hatchery, 1987.

7.5 and 13.0 ng/ml.

Results of the seawater challenge trials indicated that fish reared in regular density treatments were able to maintain blood -sodium levels below the 170 mmol/l level when exposed to 30 % seawater for a 24-h period, while fish reared at quadruple density remained slightly above 170 mmol/l (Fig. 5). Blood sodium levels of regular and quadruple densities were not significantly different from each other either prior to exposure to the seawater, or after the 24-h period. No mortalities were observed in either of the challenge groups during the trials.

cortisol concentrations were monitored as a means of recording undue stress which might occur during transfer or tagging of the fish in Drano Lake. cortisol concentrations were slightly elevated during transfer of fish out of the hatchery, but levels decreased after one and seven days after transfer (Fig. 6). A slight elevation was also noted one day after tagging. Highest cortisol levels were observed a% the conclusion of. the study in regular density treatments; cortisol levels in double density treatments were somewhat lower.

Growth and Survival of Unfed Fish

Growth of unfed fish over the entire rearing period was much slower than in hatchery control fish (Fig. 7). Fish were stocked on April 15 at a size of about 1.0 g (460/lb), and when the monitoring period was completed (June 3, after 49 days of rearing), mean size of fish reared at .026 and ,051 kg/m3 was

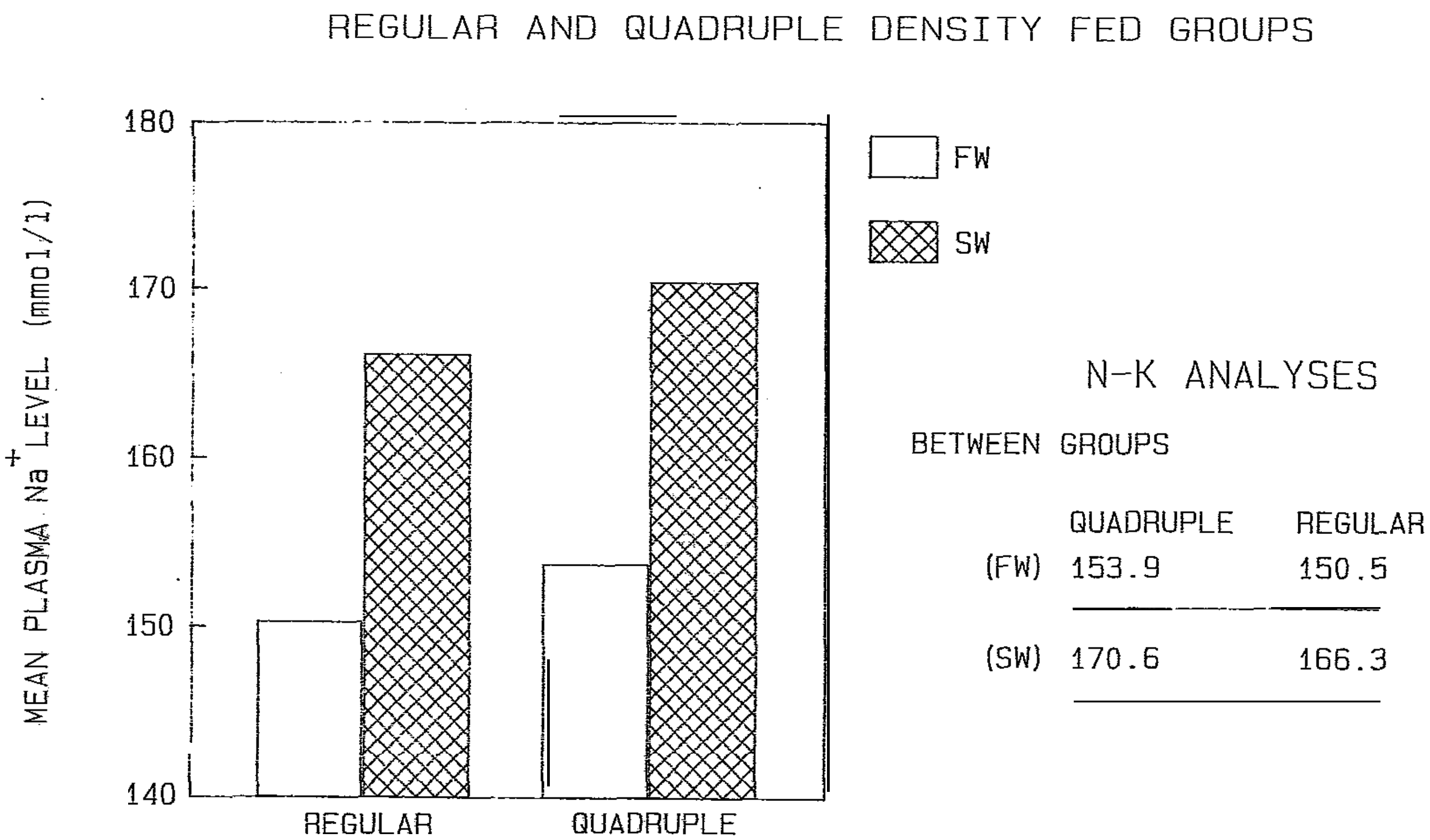


Figure 5. Results of seawater challenge trials, showing mean plasma sodium levels in freshwater (FW) and seawater (SW) after a 24-hour exposure, and summary of Newman-Keuls multiple range comparisons, Drano Lake, 1987. (continuous underlines indicate no significant difference at .05 level)

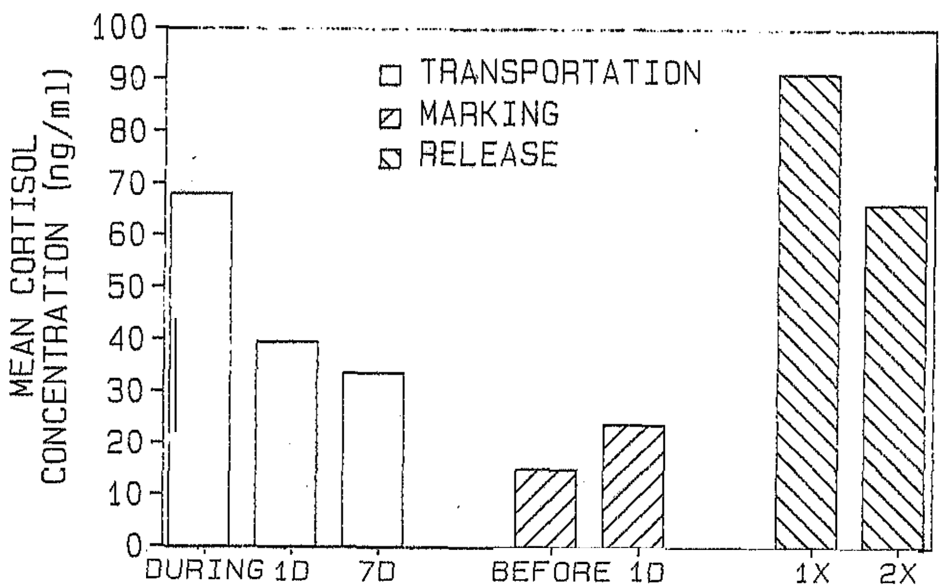


Figure 6. Blood serum cortisol concentrations (ng/ml) of fish during transfer from the hatchery, one day after transfer, and one week after transfer; one-two days prior to marking and one week after marking; and at release in regular and quadruple density treatments, Drano Lake, 1987.

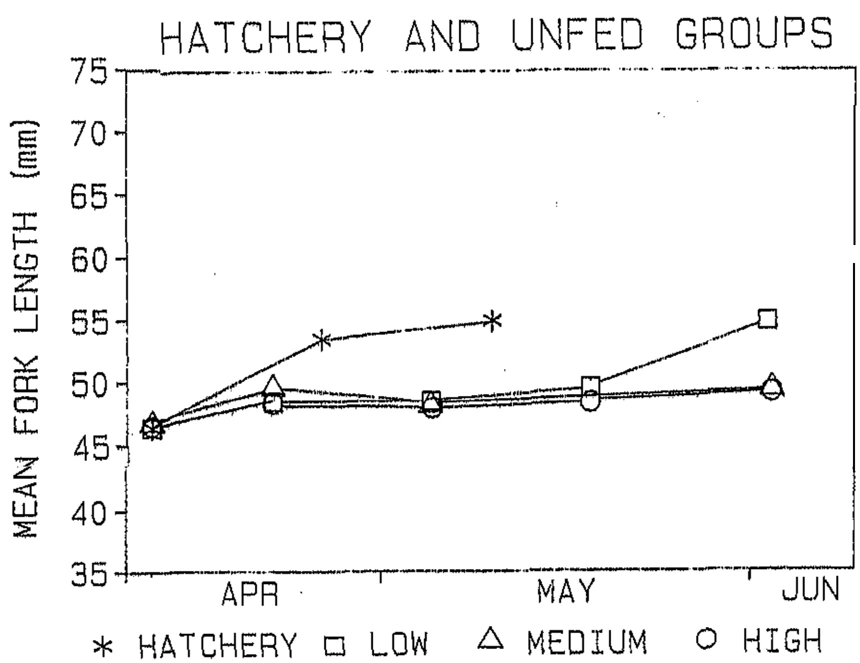


Figure 7. Mean lengths of unfed fish reared at low, medium, and high densities in Drano Lake and of control groups reared at Little White Salmon National Fish Hatchery, 1987.

Table 7. Stocking and release summaries of unfed fish stocked in pens at low, medium, and high density, Drano Lake, 1987. Final release figures summarize growth of unfed fish during the final two weeks prior to release, during which time the fish were fed.

Treatment Summary	Low		Medium		High	
Stocking Summary:						
Number	991		1982		3964	
Number/lb	450		450		450	
Mean Weight (g)	1.0		1.0		1.0	
Density (kg/m3)	.013		.026		.051	
Total Weight (kg)	1.0		2.0		4.0	
Stocking Date	April 15		April 15		April 15	
Release Summary:	Pen #		Pen #		Pen #	
	13	14	15	16	17	18
Number	896	892	1880	1873	3365	3650
Natural Mortality	0	4	11	18	503	218
(%)	(0.0)	(0.4)	(0.6)	(0.9)	(12.7)	(5.5)
Sampling Mortality	95	95	91	91	96	96
	Mean		Mean		Mean	
Number/lb	395		560		568	
Mean Weight (g)	1.15		.81		.80	
Density (kg/m3)	.013		.019		.037	
Total Weight (kg)	1.0		1.5		2.9	

actually smaller than at stocking--.61 and .80 g, respectively (Table 7). Unfed fish reared at ,013 kg/m3 grew slightly, reaching a mean size of 1.15 g (395/1b) on June 3, which was significantly larger than either of the other unfed groups (Table 8). Total weight of fish produced did not change for fish reared at .013 kg/m3 and decreased for fish reared at both higher densities.

Mortality of fish reared at.013 kg/m3 and ,026 kg/m3 was low ranging from 0 % to 0.9 % However, mortality of fish reared at .051 kg/m3 was much higher-over 5.5 % in one pen, and 12.7 % in the other.

Physiology of Unfed Fish

ATPase activity in groups of unfed fish was relatively low throughout most of the rearing period, and values generally decreased as density increased (Fig. 8). However, levels of activity observed on May 6 were uncharacteristically high for 1.0 g-fish, ranging from 10.0 units of activity for fish reared at high density to 22.7 units of activity for fish reared at low density. Subsequent activities were low during the remainder of the rearing period, and below those observed in fed fish.

Thyroxine concentrations in unfed fish remained low (leas than 5.0 ng/ml) throughout the rearing period (Fig. 9). Values were somewhat higher than in hatchery controls and much lower than among fed fish treatments.

Table 8. Summary of a one-way nested analysis of variance (ANOVA) and a Newman-Keuls multiple range test comparing size of unfed fish at the conclusion of the monitoring of the fish on June 3, using fork lengths from all three densities tested in Drano Lake during 1987. Treatments with the same grouping letter are not significantly different at the .05 level.

Summary of nested one-way ANOVA (P=.05):

Dependent Variable	Source	D.F.	ANOVA S.S.	F-Value	P>f
Fork Length	Density	2	2093.26	41.68	0.0001
	Pen(density)	3	421.81	5.60	0.0010

Summary of multiple-range test:

Variable	Density	Mean Value	N	Grouping
Fork Length	Low	54.91	101	A
	Medium	49.47	100	B
	High	49.16	97	B

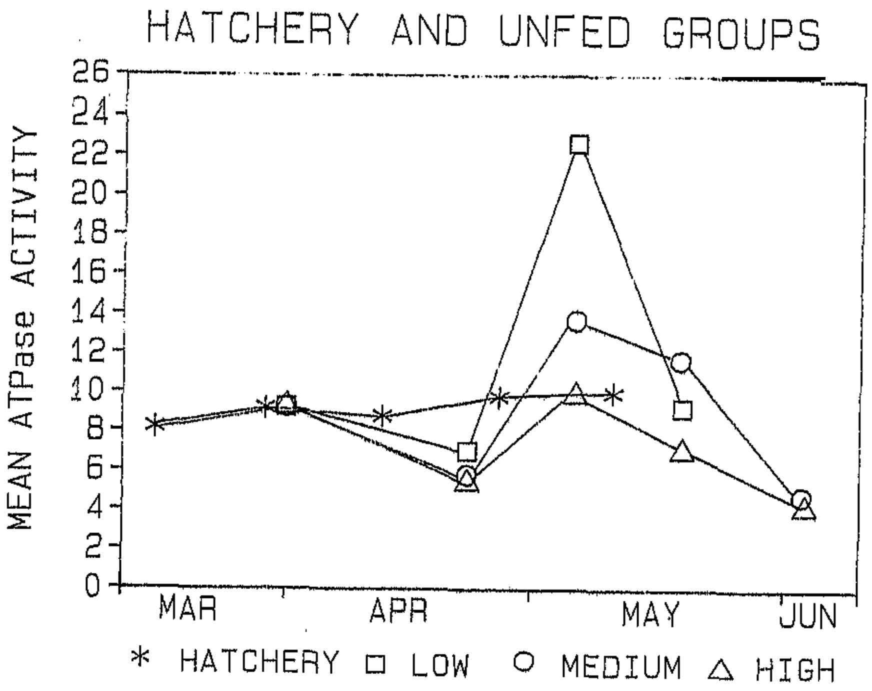


Figure 8. Mean ATPase values of unfed fish reared at low, medium, and high densities in Drano Lake and of control groups reared at Little White Salmon National Fish Hatchery, 1987.

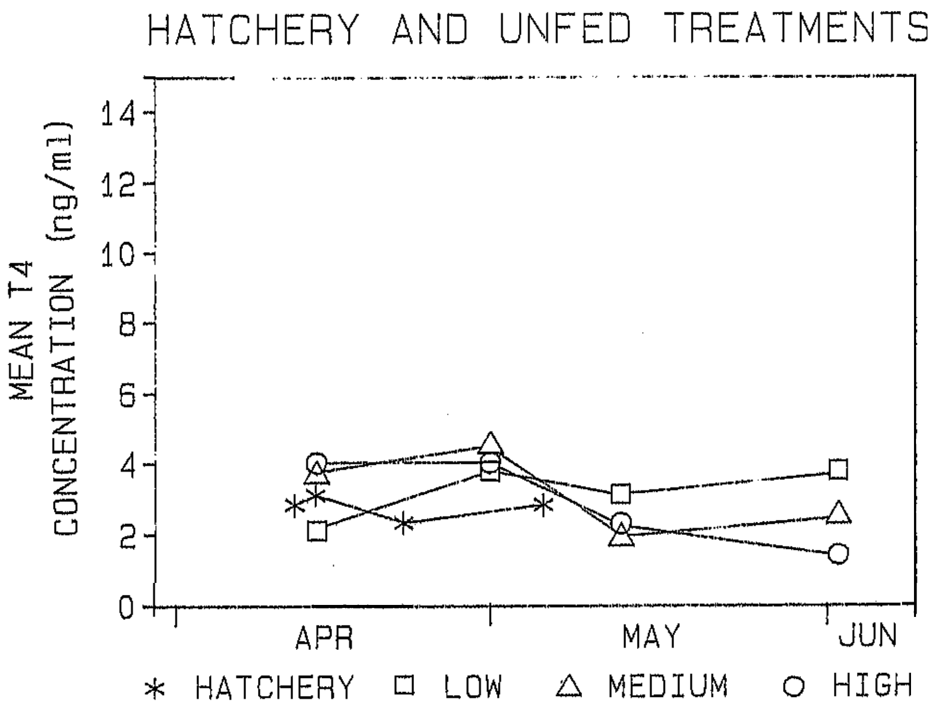


Figure 9. Blood serum thyroxine concentrations (ng/ml) of unfed fish reared at low, medium, and high densities in Drano Lake, 1987.

Utah Fish Quality Index

All groups of fed and unfed fish were monitored to asses5 effects that various rearing scenarios might have on general health and quality using the autopsy technique developed by the Utah Division of Wildlife Resources (Goede, in press). The general quality of fish reared in Drano Lake was compared to the control group reared at the LWSNFH.

Observations among groups of "fed fish were generally very similar regarding all categories (Appendices 7-10). Undesirable effects of rearing fish at the high densities tested in 1987 were not observed among samples of fish routinely collected from the four treatments of fed groups.

condition factors of all four treatments of fed fish remained relatively high throughout the rearing period, and tended to increase during the final two-four weeks. Mesenteric fat content in fed fish also increased over the period. Signs of acute stress, as indicated by severe hemorrhage in the thymus were rarely observed; mild hemorrhage was noted in up to 39-40 % of the fish in fed groups during the latter stages of the rearing period. Other observations, including blood work-ups, were normal and differences among the groups were not apparent.

Size of fish in the control groups at the hatchery were somewhat smaller over the period, and condition factors were slightly lower than observed among fed groups (Appendix 11). Blood hematocrit and serum protein concentrations were very similar to those observed in fish in fed groups. Mesenteric fat in hatchery fish was generally lower than in fed fish, but thymus hemorrhages were less prevalent. No other notable differences were apparent in comparing hatchery control fish with fed fish reared in Drano Lake.

Poor health quality of unfed fish was demonstrated by low condition factors and the extremely low serum protein levels observed ; both factors appeared to be affected by higher densities and time (Appendix 12). Blood hematocrit concentrations in unfed fish also tended to decrease during the rearing period, while those observed in groups of fed fish and in hatchery fish increased slightly. However, hematocrit levels remained within the limits of those observed in all other fish. Mesenteric fat in unfed fish was noted in only the initial sample on April 23. All other monitored fish health criteria were normal for unfed fish.

Density Relationships

Densities normally used at Spring Creek National Fish Hatchery (SCNFH) and LWSNFH for rearing upriver brights were compared with those used in the rearing of fish in off-station enclosures at all sites in terms of rearing space (spatial index), a combination of rearing space and size (density index), and a. combination of space and flow (flow index) (Table 9). Densities tested thus far include rearing scenarios ranging from 8,000 fish/pen (0.43 kg/m3) in 1964 to 76,000 fish/pen (4.20 kg/m3) in 198-l. Control groups were reared in the hatcheries during the four-year period at about 10.30 kg/m3' at SCNFH and 26.48 kg/m3 at LWSNFH.

The densities recommended for maximum growth and survival in rearing upriver brights at the temperatures and sixes used in this study is 14.30 kg/m3 for a single pass' water circulation system (Ranks et al. 1979). Off-station rearing was considered a single-pass system; the LWSNFH was using a single pass system while SCNFH was using a water treatment/reuse system during these studies. Normally reuse systems are able to rear only about one-half the densities reared in a single-pass system (Wedemeyer et al. 1981).

Maximum densities per unit volume tested during pen rearing trials have been much lower than either those actually used in the hatcheries or maximum densities recommended for use in hatcheries. Density indices (density per unit volume/mean length of fish) which are commonly used in management of national fish hatcheries were also much lower than in either of the hatcheries and less than one-third of the recommended maximum.

The entire spectrum of spatial rearing scenarios used in the pen rearing study Including fish sizes from about .5 g (900/lb), about the smallest size able to be transferred from the hatchery (J. Manning, Manager, LWSNFH, personal communication), through release size at about 100/lb, are summarized in Figure 10. Spatial density limits for temperatures encountered in Drano Lake for the rearing of chinook salmon (Banks et al. 1979) were much

Table 9. Summary of numbers of fish reared/treatment, density relationships (expressed in terms of space, density indices, and flow), and years of comparison for fish reared OFF- and ON-station during pen rearing trials at Social Security Pond, Rock Creek, and Drano Lake, 1984-87. Maximum densities recommended/rearing facility based on fish at a release size of about 100/lb(4.5g).

Number/ Treatment	Space Density lb/ft3(kg/m3)	Density Index\a	Flow Index\a <u>lb/g/m</u> length(inches)	Years Compared
OFF-STATION:				
8,000	0.027 (0.43)	.0094	.07-.32	1984
18,500	0.065 (1.05)	.0226	.18-.74	1984,-85,-86,-87
37,000	0.131 (2.10)	.0456	.35-1.48	1986,-87
55,000	0.196 (3.15)	.0683	.56-2.22	1986,-87
75,000	0.265 (4.20)	.0923	.74-3.00	1987
ON-STATION:				
250,000(SCNFH)	0.65 (10.30)	.2265	1.20	1984,-85,-86
250,000(LWSNFH)	1.67 (26.48)	.5818	1.90	1986,-87
MAXIMUM:	0.90 (14.30)\a	.35-.40\c	1.23-1.76	

a\ Piper et al. 1982 (from Wedemeyer and Wood 1974). Including the range of temperatures from 9 to 14 C and based on a water exchange in net pens of 1 to 4 hours.

b\ Banks et al. 1979.

c\ U.S.F.W.S. hatchery practices.

higher over the range of growth observed thus far in the pen rearing study.

Water exchange in net pens has been extremely difficult to measure since pens are subject to continually, changing water currents. However, using dye and the subsequent observation of flushing time through a pen at Drano Lake on a calm day (O-5 mph -winds), it was estimated that approximately four hours were required for complete exchange, as indicated by the disappearance of the dye from the enclosure. It was therefore concluded that a four-hour exchange would be near maximum, at least in Drano Lake, and that increased wind velocities would increase water exchange.

A flow index fox rearing fish in a net pen was constructed using the estimated water exchange rates, and conclusions developed from the above exercise as an example of the range of flow indices which may be encountered when rearing fish *in* pens (Table 9). Flow indices of maximum densities tested in 1987, quadruple treatments, ranged from 0.74-3 .OO lb/g/min using an estimated water exchange rate from one to four hours. Flow indices of other high density treatments, including double and triple densities, were also relatively high during periods of numbers of fish reared per raceway, employing flows and temperatures normally used, were 1.20 and 1.90, respectively.

Figure 10 represents maximum recommended flow densities at the range of temperatures encountered. during 1987 (9 C to 14 C), over the range of sizes of fish reared (unshaded,). Maximum flow indices tested (quadruple treatments thus fax represent the size

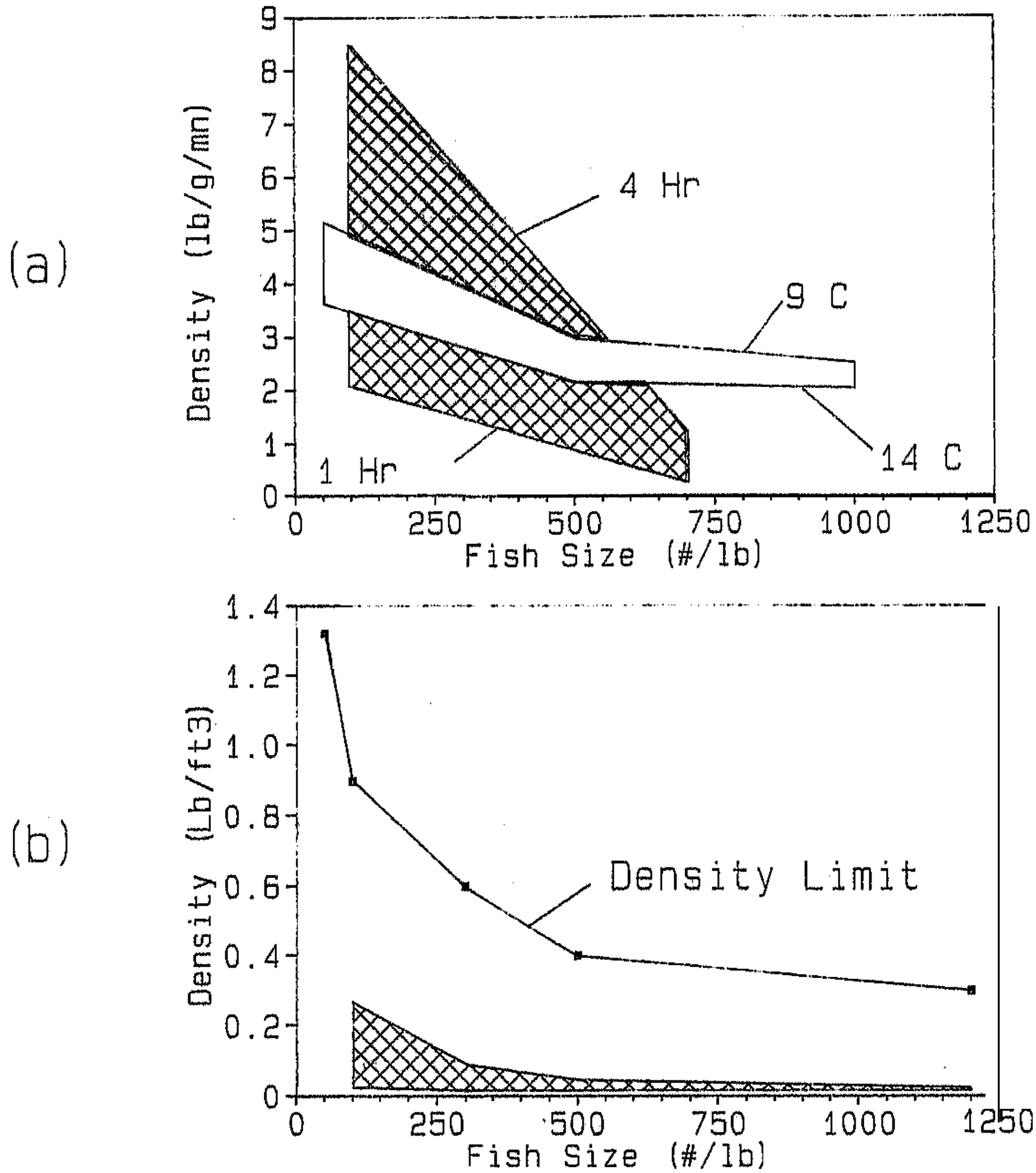


Figure 10. Densities tested in pen rearing trials in terms of flow (a) and space (b). (a) Flow relationships (lb/g/mn) include quadruple density with a range of water exchange in a net pen of one-four hours (shaded); unshaded area represents the maximum density recommended for the range of temperatures encountered in Drano Lake in 1987. (b) Density expressed in terms of weight/unit of volume (lb/ft3) with shaded area representing the range of densities tested in pen rearing trials thus far; maximum recommended densities/unit volume are depicted as "density limit" over the range of sizes reared off-station.

limited water exchange in reation to the maximum recommended flow index for chinook salmon. Regular density *treatments were* below the maximum recommended flow index.

Flow indices in the hatcheries were much more predictable because of the unidirectional *control* available in a hatchery raceway. At SCNFH and LWSNFH the flow indices calculated for the range of 'fish reared in Drano Lake in 1987 (7OO/lb to lOO/lb) at water exchange rates ranging from one-four hours (shaded). Flow indices for pens with larger-sized fish at quadruple density would exceed the recommended maximum during periods of reduced water exchange, but in the presence of higher exchange rates, fish reared at this density would be below the maximum, even at higher water temperatures.

Costs of Rearing Fish in Net Fens

Rearing scenarios tested during the past 4 years are summarized in Table 10. Stocking and release sizes were standardized (2.0 g at stocking and 4.5-6.0 g at release) in order that some of the variables in the cost comparisons could he minimized However, other variables included in the comparisons, primarily operation/maintenance and labor expenses, are subject to changes in management procedures, and may be higher, or lower than the estimated expenses presented in this report.

In addition, costs presented and used in developing hatchery efficiency ratios (Senn et al. 1984) include the use of, and

Table 10. Rearing scenarios tested during pen rearing trials using a stocking size of about 2.0g and a release size of 4.5 to 5.0 g, with ranges of predicted costs for all factors involved in the rearing of 1000 lb of fish. Expense items include those categorized as "fixed/initial" including all initial rearing equipment required for the study, and "variable/annual" including all recurring expenses which would be subject to changes affected by operation.\a Hatchery efficiency ratios for each rearing scenario is included for the range of densities tested in 1987.

Expense Item\b	Regular Density (.065 lb/ft3)	Double Density (.131 lb/ft3)	Triple Density (.196 lb/ft3)	Quadruple Density (.265 lb/ft3)
Fixed/initial:				
Frames, anchors,etc.	$ 16,515-19,737	$ 8,056- 9,667	$ 5,438- 6,646	$ 4,028- 4,834
Feeders	3,403- 4,067	1,660- 1,992	1,120- 1,370	830- 996
Nets & covers	4,715- 5,635	2,300- 2,760	1,552- 1,898	1,150- 1,380
Total	$ 24,633-29,439	$ 12,016-14,419	$ 8,110- 9,914	$ 6,008- 7,210
Variable/annual:				
Feed costs	$ 400- 550	$ 300- 450	$ 350- 400	$ 425- 425
O & M	1,472- 2,944	600- 1,442	405- 991	300- 721
Labor	2,460- 3,675	1,200- 1,800	810- 1,238	600- 900
Total	$ 4,332- 7,169	$ 2,100- 3,692	$ 1,565- 2,629	$ 1,325- 2,046
Number of pens required:	8.2 - 9.8	4.0 - 4.8	2.7 - 3.3	2.0 - 2.4
Hatchery Efficiency Ratio ($/lb) :	$ 7.72 - 8.97	$ 3.70 - 5.58	$ 2.65 - 3.92	$ 2.13 - 2.99

a\ The estimated costs listed here may be higher than those observed during actual rearing trials because growth of fish was somewhat higher in our studies than conservatively estimated in these expenses.

b\ Expenses included as follows: 1) Frames, anchors, etc.-$2,014; 2) Feeders-$415; 3) Nets & covers-$575; 4) Abernathy dry feed-$0.45/lb; 5) Operations & Maintenance figured at between 5 and 10 %; 6) Labor figured at between .012 and .015 man-year/pen at $25,000/yr.

reflect the cost of, aluminum-framed pens; other types of framing may be more cost-effective over an extended period,. Therefore, the costs of alternative pen frames have been solicited, and are included in Table 11.

A range of expenses, and the estimated numbers of pens required per 1000 lb of fish reared., was calculated based on the results of the pen rearing trials during the past four years (Table 10). A range of estimated expenses was included to account for differences in growth, release size, and length of the rearing period. By increasing the numbers of fish reared per pen from regular to quadruple density, fixed/initial costs, as well as variable/annual expenses, were decreased considerably. Numbers of pens needed to produce 1000 lb of fish were reduced from 9.8 pens, to 2.0 pens.

Aluminum frames are the least expensive, with initial expenses for equipment of $3,216 (Table 11). Polyethylene frames, the most recent entry into the market, cost about $5,565, while wooden walkway frames cost about $5,365' per unit; wooden walkways are less expensive when 'constructed in arrays of several net pens which share common sides.

Labor for set-up and weight of framing would be important considerations for managers if net pen rearing were to be applied on a management basis for rearing fish in backwaters along remote sections of the Columbia River. Estimated labor set-up costs per unit range from $50-$125, with cost of set-up of polyethylene frames the lowest. Aluminum frames are relatively light at 400

Table 11. Various commercially available pen-rearing facilities including aluminum, polyethylene, and wooden walkway framing. Expenses for wooden walkways include those for a single pen, and for a multi-pen array. Costs of aluminum and polyethylene framing would not be affected by multi-pen arrangement. Hatchery efficiency ratios for rearing 1000 pounds of fish at regular density are included for all facilities.

Item	Aluminum\a	Polyethylene\b	Wooden Walkway\a One Pen	Wooden Walkway\a Array
Frame (20'x20')	$ 1,800	$ 3,700	$ 3,500	$ 2,500
Anchor (75-100 lb)	150	600	600	400
Net (20'x20'x13')	750	750	750	750
Feeder	415	415	415	415
Cover	100	100	100	100
Total	$ 3,215	$ 5,565	$ 5,365	$ 4,165
Set-up costs ($) \c	75	50	125	100
Set-up costs (man-hours)	6	4	8	10
Frame weight (lbs)	400	100	8,000	---
Efficiency Ratio ($/lb)	$ 7.72	$ 9.53	$ 9.96	$ 8.59

a\ Topper Industries, Vancouver, WA (1987 prices).

b\ Industrial Plastics, Washougal, WA (1987 prices).

c\ Set-up costs include labor for assembly of each frame, installation of nets, anchoring, and final emplacement.

pounds per unit, while wooden walkways weigh about 8,000 pounds per unit; polyethylene frames weigh about 1000 pounds per unit. All three types of frames could be disassembled, transported or stored, and reassembled at a targeted rearing site, but transferring the lighter assemblies would be a simpler task.

Estimated hatchery efficiency ratios using rearing scenarios tested during the present study, and employing aluminum net pens, ranged from $ 2.13/lb at quadruple density to a maximum of $ 8.97/lb at regular density. Efficiency ratios comparing the rearing of fish at regular density using alternate facilities reflected the initial higher costs of polyethylene and wooden walkways (all frames were given a 20 year usage: in practice, usage may be extended or shortened, depending on care). Estimated efficiency ratios ranged from $7.72/lb using alumimun pens to $9.96/lb for single wooden walkway design.

Adult Recoveries

Adult recoveries of fish released from Rock Creek and Social Security Pond in 1984 and X985, and additionally from the hatchery in-river harvest are included with fish recovered at the respective sites. Fish recovered as "2's" were precocious males "jacks"; the only other adult return information available was the recovery of three-year old fish from the 1984 releases.

No fish were recovered at Social Security Pond from either 1984 and 1985 release groups. However, jacks and three-year old

Table 12. Adult recoveries from releases at Rock Creek (RC), Social Security Pond (SSP), and Little White Salmon Hatchery (H) during pen rearing trials in 1984 and 1985, including on-site, ocean and in-river recoveries. (Data includes only coded wire tagged recoveries.)

Release Year	Number Released	Tag Code	On-site Recovery				Ocean Recovery				In-river Recovery			
			2's	3's	4's	5's	2's	3's	4's	5's	2's	3's	4's	5's
1984	73,804	SSP(H5-6-6)	0	0			3	32			8	14		
	76,831	RC(H5-6-7)	10	1			5	103			10	58		
1985	99,169	SSP(H5-7-2)	0				9				3			
	105,406	SSP(H5-7-3)	0				14				6			
	117,025	RC(H5-7-1)	4				13				8			
	115,937	RC(H5-7-4)	2				10				0			
	62,960	RC(H5-7-5)	3				0				0			
	66,679	RC(H5-7-6)	7				1				0			
	19,455	H(5-12-50)	0				0				0			
	19,340	H(5-12-51)	0				9				0			
	21,024	H(5-12-56)	0				0				0			
	25,430	H(5-12-57)	2				0				0			
	16,807	H(5-12-52)	0				5				0			
	17,714	H(5-12-53)	2				0				0			
	24,488	H(5-12-54)	0				0				3			
	24,525	H(5-12-55)	1				3				0			

fish were recovered in ocean and in-river harvest. Jacks from fish reared at Rock Creek were captured at the rearing site both years, but only one adult has been captured. Ocean and in-river recovery of Rock Creek fish, however, has been much better than that of either Social Security Pond or hatchery controls.

DISCUSSION

The decision to move pen rearing trials to Drano Lake in 1987 presented an opportunity for continued testing of rearing densities, even though potential disease problems recognized at the hatchery percluded the transfer of fish to Rack Creek and Social Security Pond, When IHN was diagnosed in upriver bright juveniles at the hatchexy, they were disposed of, eliminating any future comparison between adult and hatchery recoveries' for releases made in 1987. however, a comparison of growth and physiology of fish in the hatchery and in the pens was possible over an B-week period., and the occurrence of IHN in hatchery fish,, and not in fish reared off-station was an observation which may be noted in future,, rearing strategies in dealing with disease problems in hatcheries.

Growth and physiological development of hatchery fish had basin somewhat behind the fed groups in net pens through the last week in April On the final date of comparison, growth and ATPase activity of fish in the hatchery had fallen significantly behind fed fish in Drano Lake, Temperatures increased in Drano Lake during this period from about 10 C to over 14 C, while temperatures in the hatchery remained around 9 C over the entire rearing period. There was no way of determining if the impending effects of the virus had slowed the development of hatchery fish. The potential for some effect on the hatchery fish existed, even at the low rates of infection diagnosed in the raceway monitored as a control.

IHN was diagnosed in fish reared in all raceways in the hatchery. Therefore the likelihood that fish transferred into the net pens had been exposed to IHN in the hatchery was high. When intensive sampling of the Drano Lake fish for disease failed to detect any signs of pathogens, speculation about the absence of IHN in net pens led to a combination of three conclusions (personal communication James R. Winton Seattle National Fishery Research Center): 1) temperatures of below 9 - 10 C (Little White' Salmon raceways) would tend to increase the incidence of the outbreak, while temperatures above 10 C (Drano Jake temperatures) would decrease incidence; 2) the lower densities of fish in net pens than in hatchery raceways, also tended to reduce the incidence of the disease: 3) the fish reared in net pens were probably from earlier egg takes at the hatchery, and had a lower titer than did later egg takes.

The cool water temperatures in Drano Lake resulted in slower rates of growth than those observed during previous years of off-station rearing at Rook Creek and Social Security Pond;

density differences noted in 1986 studies were not apparent in 1987. In addition, blood-Na levels and ATPase activities in high (quadruple) and regular densities at release were similar, indicating that physiological development among the various densities of fed fish in Drano Lake proceeded at a similar rate. Mortality was slightly higher in higher density treatments, but remained low in all treatments throughout the rearing period.

The possibility of a Ceratomyxa outbreak, as well as IHN, existed throughout the rearing period. Therefore, a small group of fish reared at regular density was held for an additional two-week period after release to extend the test of the incidence of either of the diseases, as well as other pathogens which might potentially affect rearing of fish in backwaters. This group of fish remained healthy and physiolotical development continued to proceed normally

The collection of fish passing through Bonneville Dam indicated that released fish had in fact, passed out of Drano Lake and actively migrated downstream during the first week following release (personal communication, Katie Timmerman National Marine Fisheries Service, Bonneville Dam). These fish continued to grow, and ATPase activities had increased during the interim.

Unfed fish grew poorly in Drano Lake. Although final zooplankton sampling analyses were not available, preliminary observations indicated that populations were much lower in Drano Lake than at Rock Creek in either 1985. or in 1986. slow rates of growth among unfed treatments at Rack Creek in 1985 and' 1986 were attributed to low densities of zooplankton. Available food, primarily zooplankton, apparently limited growth of unfed fish in Drano Lake. While available food was sufficiently abundant to marginally maintain unfed fish at the low density, and to a lesser extent, medium density, there was insufficient food available for high density fish, resulting in the mortalities.

Observed physiological activity of unfed fish was unexpected, at least in the respect of what was observed among unfed fish in previous years. The limited availability of food, and resulting perceived starvation, may have triggered a physiological response when conditions changed as food became more abundant during the last week of April and first week of May. 'These changing conditions resulted in a limited amount of growth, and the development of unusually high ATRase values in relation to all other treatments observed.

It is difficult to determine optimal densities for growth and development of fish in net pens, primarily because of the relationship water exchange has with available rearing space. in areas where unidirectional forces occur, passage of water through a net pen may be estimated with a certain amount of precision. However in backwaters, where water exchange is subject to incalculable effects, water: exchange is much more difficult to assess. For this reason, densities of fish reared in net pens during these studies 'have tended to be low in relation to the densities of fish reared in hatcheries and in other pen rearing scenarios (Senn et al. 1984).

The attempt to address this problem by observing the passage of dye through. a pen was no% conclusive However, these observations confirmed that a cautious approach to the rearing of large numbers of fish, was advisable, especially in situations where long periods of quiet water conditions would be encountered. Even though densities of fish reared in pens have remained below what are considered "maximum" in terms of space, quadruple densities may have actually approached a maximum during periods when water exchanges within the pens are extended. No indication of limited water exchange have been observed during, pen rearing trials thus far (low concentrations of dissolved oxygen, high concentrations of ammonia), which may indicate that maximum numbers per enclosure remain untested,.

Costs of rearing fish using net pens are obviously affected by the numbers of fish per enclosure i.e. the more fish per pen, the lower the costs. In addition, the type of enclosure, the length of service expected from the enclosure,, and the amount and type of service (labor, operation/maintenance) required during the rearing of the fish must be considered in order to develop a range of expected expenses using the densities tested.

The range of expenses calculated for densities. tested during these studies include expenses associated with net pens constructed with aluminum frames. Aluminum framing was initially purchased for these studies because of the lower cost and ease of assembly. A rearing facility that could be transferred and reassembled at remote sites was necessary, since, in practice rearing sites might change yearly, depending on the rearing scenarios desired. The frames have been easily transferred, and are light and efficient to reassemble. However, the frames require a relatively high amount of maintenance, especially in high winds or waves.

Other framing including polyethylene and wooden walkways, may have advantages over the aluminum frames which would make the initially-higher investment worthwhile, especially for managers who intend to employ net 'pen rearing routinely in their operation. Advantages of polyethylene framing include durability and ease of transport and assembly, while wooden walkways provide an exiremely stable and substantial system; both types of framing have extended, predicted periods of usage. The primary disadvantage of polyethylene framing is the high initial cost; wooden walkways are difficult to transfer between sites once In place.

Adult returns to the sites of release have been lower than anticipated. Recoveries in the ocean and In-river harvest were encouraging, however. The returns, although preliminary as far as final camparisons and cost/benefit analyses are concerned, indicate that survival of fish r&eased off-station to adult, especially from Rock Creek, in 1.984 and 1985 was good.

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REFERENCES CITED

Banks, J.L., W.G. Taylor, and S.L. Leek. 1979. Carrying capacity recommendations for Olympia Area National Fish Hatcheries, Mimeo Report . Abernathy Salmon Cultural Development Center, Longview, Washington. 44pp.

Folmar, L.C and W.W. Dickoff. 1981. Evaluation of some physiological parameters as predictive indices of smoltification. Aquaculture. 23:309-324.

Goode, R.W. Necropsy based fish health assessment. Utah Division of Wildlife Resources. In press.

Novotny, J.F., T.L. Macy, and J.T. Gardenier. 1984. Pen rearing and imprinting of fall chinook salmon Annual Report 1983. Prepared by U.S. Fish and Wildlife Service for Bonneville Power Administration, Portland, Oregon. 25 PP.

Novotny, J.F., T.L. Macy, and J.T. Gardenier. 1985. Pen rearing and imprinting of fall chinook salmon: Annual Report 1984. Prepared by U.S. Fish and Wildlife Service for Bonneville Power Administration, Portland, Oregon. 61pp.

Novotny, J.f., T.L. Macy, and J.T. Gardenier. 1986a. Pen rearing and imprinting of fall chinook salmon: Annual Report 1985. Prepared by U.S. Fish and Wildlife Service for Bonneville Power Administration, Portland, Oregon. 65pp.

Novotny, J.F., T.L. Macy, J.T. Gardenier, and John W. Beeman. 1986b. Pen rearing and imprinting of fall chinook salmon: Annual Report 1986. Prepared by U.S. Fish and Wildlife Service for Bonneville Power Administration, Portland, Oregon. 78pp.

Piper, R.G., I.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler J.R. Leonard. 1982, Fish Hatchery Management. U. S. Fish and Wildlife Service, Washington, D.C. 517pp.

Schreck, C.B. 1982, Stress and compensation in teleostean fishes: Responses to social and physical factors. Pages 295-32 in Stress and Fish,, A.D. Pickering (ed.). Academic Press, New York.

Senn, J.J. Mack, and L. Rothfus. 1984. compendium of low-cast Pacific Salmon and steelhead trout production facilities and practices in the Pacific Northwest. Pub. by Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon. 488pp.

Wedemeyer, G.A. and J.W. Wood. 1974. Stress as a predisposing factor in fish diseases, Fish Disease Leaflet 38, U.S. Dept. of Interior, Fish and Wildlife Service, Washington, D.C. 8pp.

Wedemeyer, G.A., R.L. Saunders, and W.C. Clarke. 1981. The hatchery environment required to optimize smoltification In the artificial propagation of anadromous salmonids Pages 6-20 in L.J. Allen and E.C. Kinney, eds. Proceedings of the Bio-Engineering Symposium fox Fish Culture. American Fisheries Society, Bethesda, Maryland.

Zar, J.G. 1984. Biostatistical Analysis. Prentice-Hall Inc., Englewood Cliffs, Mew Jersey.

Zaugg, W.S. 1982 A simplified preparation for adenosine triphosphatase (ATPase) determined in gill tissue. Can. J. of Fish. Aquat. Sci. 39:215-217.

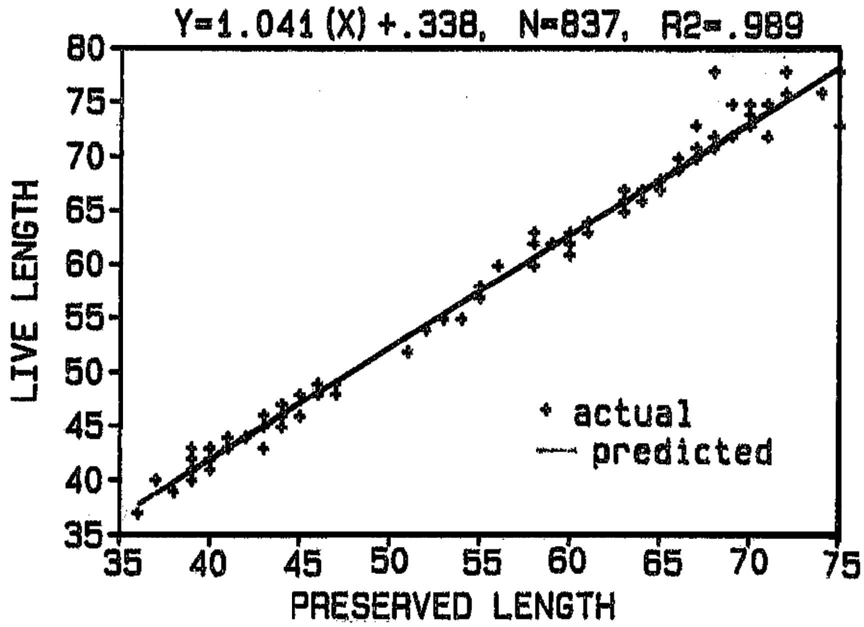
Appendix 1. Tagging and retention summaries for fish coded wire tagged during pen rearing studies, 1987.

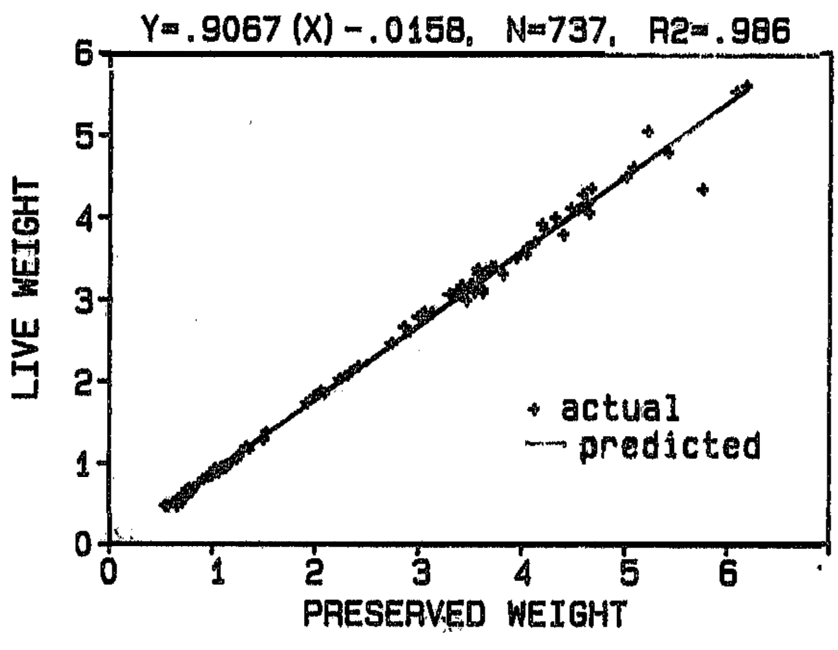
Regular Density

Stocking date	4/12	4/13	4/14	4/14 & 15
Code	5B-1-1	5B-1-2	5B-1-3	5B-1-4
Total tagged	55,532	55,266	55,407	53,888
Total mortality	820	777	686	571
Total Released	51,954	54,489	54,712	53,326
Adipose clip/no cwt	3,221	4,414	4,213	5,546
No clip/with cwt	883	218	492	213
No clip/no cwt	104	0	55	160
Total clipped/cwt released	47,746	49,857	49,952	47,407

High Density

	Double		Triple		Quadruple	
Stocking date	4/10 & 11		4/8 & 9		4/3 to 7	
Code	5B-1-6	5B-1-5	5B-7-14	5B-7-13	5B-2-2	5B-2-1
Total tagged	37,060	37,151	55,193	55,068	75,228	75,176
Total mortality	301	459	745	755	979	708
Total released	36,759	36,892	54,448	54,313	74,249	74,468
Adipose clip/no cwt	2,022	3,579	4,356	2,987	8,539	11,394
No clip/with cwt	404	1,660	1,525	1,304	3,044	2,383
No clip/no cwt	110	0	272	326	520	1,042
Total clipped/cwt released	34,223	31,653	48,295	49,696	62,146	59,649





Appendix 2. Preserved/live comparisons of lengths and weights, and respective regression formulas calculated from repeated measurements and weights of live fish collected throughout the rearing period, 1987.

Appendix 3. Summary of size estimates completed on release groups of regular density pens, including standard water-weight hatchery procedures (number of fish/pound and mean size in grams), weights of fish preserved in 10% formalin, weights of the preserved fish converted to live weights using the preserved/live regression formula, and individual live weights of representative samples of the group at release.

Pen Number	Water Wt. (#/lb)	Water Wt. (g)	Preserved Wt.(g)	Converted Live Wt. (g)	Live Wt. (g)
1	117.8	3.85	4.07	3.67	(Mean for all pens)
2	116.9	3.88	3.87	3.49	"
3	99.4	4.57	4.77	4.31	"
4	98.7	4.60	5.18	4.68	"
5	99.0	4.59	4.60	4.16	"
6	95.7	4.74	4.97	4.49	"
7	88.3	5.14	5.17	4.67	"
8	102.8	4.42	4.78	4.32	"
9	96.2	4.72	4.32	3.90	"
10	122.2	3.72	3.91	3.53	"
11	89.0	5.10	4.90	4.42	"
12	86.5	5.25	5.28	4.77	"
Mean	101.0	4.55	4.65	4.20	4.39
N	4374	4374	394	394	35

Appendix 4. Chronology of events for rearing, transfer, and release during the pen rearing trials in 1987.

Date	Activity
9/1/86-9/30/86	Adults captured at Bonneville Hatchery (Oregon Dept. of Fish and Wildlife) fish traps and fish ladder at Bonneville Dam and at Little White Salmon National Fish Hatchery (LWSNFH).
12/1/86-12/22/86	Eggs spawned and hatched at LWSNFH.
1/1/87-3/1/87	Fish reared and ponded at LWSNFH.
1/7/87	Pen rearing personnel informed that adult chinook broodstock spawned for pen rearing fish had been tested positive for infectious hematopoietic necrosis (IHN). Eggs from the entire upriver bright egg take had been subsequently exposed to IHN virus in the rearing water at LWSNFH.
2/25/87	Drano Lake suggested as a potential alternative rearing site in the event that transfer of fish from the LWSNFH was not approved or that fish for the study could not be obtained from another source.
2/27/87	Drano Lake was selected as an alternative rearing site after efforts to obtain fish for the study elsewhere failed; transfer of the 1987 field work to that site was approved by BPA.
3/2/87-3/10/87	Rearing equipment was transferred from Rock Creek and Social Security Pond to Drano Lake.
3/12/87	Fish transferred from LWSNFH raceways to temporary pens in Drano Lake.
3/18/87	Final Transfer of fish from LWSNFH raceways to Drano Lake net pens.
4/1/87-4/15/87	Coded wire tagging completed on all fish held in net pens in Drano Lake.
4/27/87	Mortality increases noted in raceways at LWSNFH. IHN was presumptively diagnosed by the Lower Columbia River Fish Health Center.
5/5/87	IHN positively confirmed in LWSNFH raceways.

Appendix 4 continued.

5/6, 7, & 11/87	All net pens intensively sampled for signs of IHN by Lower Columbia Fish Health Center biologists.
5/20/87	All upriver bright stock reared in LWSNFH raceways destroyed.
5/20/87- 5/22/87	Fed treatments in net pens released.
6/16/87	Fish in unfed treatments released.

Appendix 5. Weekly natural mortality of fish in pens at Drano Lake, 1987 after being split into respective treatments.

Pen Number	DATE											
	4/4	4/11	4/18	4/25	5/2	5/9	5/16	5/23	5/30	6/6	6/16	Total
Regular Density												
1			4	14	1	0	1	0				20
2			1	25	0	2	1	13				42
3			0	23	0	2	0	3				28
4			0	17	0	0	3	2				22
5			5	1	0	4	4	4				18
6			1	130	0	11	3	17				162
7			1	14	1	3	1	4				24
8			5	56	1	0	3	4				69
9			1	15	0	1	2	1				20
10			2	12	0	5	4	33				56
11			5	41	0	0	1	3				50
12			2	82	0	0	1	10				95
Unfed Treatments												
13			0	0	0	0	0	0	0	0	0	0
14			0	0	0	2	0	0	1	1	7	11
15			0	2	0	0	0	5	3	1	20	31
16			0	0	0	2	1	9	5	1	11	29
17			0	2	1	6	6	67	271	150	14	517
18			1	5	0	3	3	31	163	283	12	501
Double Density												
19		1	3	23	0	9	1	33				70
20		1	6	163	0	8	2	53				233
Triple Density												
21		170	10	205	0	16	0	86				487
22		134	2	169	2	24	10	59				400
Quadruple Density												
23	1	189	6	96	1	32	3	287				615
24	28	136	1	4	5	4	1	140				319

Appendix 6. Comparison of: (A) gill Na-K ATPase activity among fed treatments at release and (B) among fed treatments and hatchery control fish on the final week of comparison using a one-way analysis of variance (ANOVA). A Newman-Keuls multiple range test was used to distinguish among differences which occurred when comparing hatchery control fish with off-station fish. Treatments with the same grouping number are not significantly different at the .05 level.

A. Fed treatments at release:

One-way ANOVA:

Dependent Variable	Source	D.F.	ANOVA S.S.	f-value	P>f
ATPase	Treatment	3	48.33	0.48	0.697

(no significant difference at .05)

B. Fed treatments and hatchery controls during final week of rearing:

One-way ANOVA:

Dependent Variable	Source	D.F.	ANOVA S.S.	f-value	P>f
ATPase	Treatment	3	226.30	6.56	.0003

Multiple Range Test:

Variable	Treatment	Mean Value	N	Grouping
ATPase	Quadruple	16.15	10	A
	Regular	15.18	10	A
	Triple	14.68	10	A
	Double	13.94	10	A
	Hatchery	9.98	10	B

Appendix 7. Summary of health indices of regular-density fish reared in pens using the Utah Fish Quality Indexing methodology, Drano Lake, 1987. (c.v. = coefficient of variation)

Observation	3/1a	4/1a	4/15	4/29	5/12	5/20
Fork Length(mm)	41.4	44.2	48.7	56.3	66.0	71.0
(c.v.--%)	(3.9)	(16.6)	(6.7)	(6.7)	(4.9)	(6.2)
Weight(g)	.74	.81	1.09	1.95	3.16	4.02
(c.v.--%)	(10.2)	(22.5)	(22.0)	(20.5)	(16.6)	(20.4)
Kfl	1.05	1.09	1.08	1.08	1.10	1.11
(c.v.--%)	(7.8)	(8.1)	(6.4)	(4.9)	(5.8)	(7.7)
Blood hematocrit	36.5	33.9	33.5	34.7	38.0	42.4
(c.v.--%)	(8.5)	(13.0)	(8.2)	(4.3)	(10.4)	(11.9)
Blood leucocrit	<1	<1	<1	<1	<1	<1
Serum protein	7.0	6.9	6.0	6.4	6.7	6.4
(c.v.--%)	-	(11.7)	(3.5)	(4.7)	(8.7)	(8.2)
Eyes						
Normal(%)	100	100	100	100	100	100
Gills						
Normal(%)	100	100	100	100	100	100
Pseudobranchs						
Normal(%)	100	100	100	100	100	100
Thymus						
Normal(%)	100	95	100	95	60	95
Mild hemorrhage	-	5		5	40	5
Mesenteric fat						
None	15	10		-		
Little	85	90	100	20	-	10
Normal	-	-		80	45	90
Above normal	-	-		-	55	
Spleen						
Normal(%)	100	100	100	100	100	100
Hind gut						
Normal(%)	100	100	100	100	100	100
Kidney						
Normal(%)	100	100	100	100	100	100
Liver						
Normal(%)	40	100	65	100	100	100
Pale	60	-	35	-	-	-
Mesentery						
Normal(%)	100	100	100	100	100	100

a/ Temporary pens.

Appendix 8. Summary of health indices of double-density fish reared in pens using the Utah Fish Quality Indexing methodology, Drano Lake, 1987. (c.v. = coefficient of variation)

Observation	4/15	4/29	5/12	5/20
Fork Length(mm)	48.4	56.3	67.0	69.0
(c.v.--%)	(6.6)	(6.7)	(7.1)	(9.3)
Weight(g)	1.11	1.95	3.56	4.01
(c.v.--%)	(20.1)	(20.5)	(23.9)	(28.2)
Kfl	0.96	1.08	1.15	1.22
(c.v.--%)	(5.8)	(4.9)	(8.3)	(11.1)
Blood hematocrit	31.0	34.7	39.0	38.9
(c.v.--%)	(8.9)	(4.3)	(9.9)	(10.3)
Blood leucocrit	<1	<1	<1	<1
Serum protein	6.1	6.4	6.8	6.3
(c.v.--%)	(5.6)	(4.7)	(7.5)	(8.7)
Eyes				
Normal(%)	100	100	100	100
Gills				
Normal(%)	100	100	100	100
Pseudobranchs				
Normal(%)	100	100	100	100
Thymus				
Normal(%)	100	95	90	70
Mild hemorrhage	-	5	10	30
Mesenteric fat				
None	-			-
Little	100	20	10	50
Normal	-	80	45	50
Above normal	-	-	45	-
Spleen				
Normal(%)	100	100	100	100
Hind gut				
Normal(%)	100	100	100	100
Kidney				
Normal(%)	100	100	100	100
Liver				
Normal(%)	100	100	100	100
Pale	-	-	-	-
Mesentery				
Normal(%)	100	100	100	100

Appendix 9. Summary of health indices of triple-density fish reared in pens using the Utah Fish Quality Indexing methodology, Drano Lake, 1987. (c.v. = coefficient of variation)

Observation	4/14	4/28	5/13	5/21
Fork Length(mm)	48.4	54.6	68.0	70.9
(c.v.--%)	(5.3)	(7.5)	(6.0)	(8.0)
Weight(g)	1.16	1.84	3.46	4.17
(c.v.--%)	(16.9)	(24.7)	(19.2)	(22.7)
Kfl	1.01	1.10	1.09	1.15
(c.v.--%)	(3.8)	(6.1)	(4.7)	(7.7)
Blood hematocrit	33.4	35.3	39.9	39.5
(c.v.--%)	(10.5)	(7.6)	(7.6)	(9.8)
Blood leucocrit	<1	<1	<1	<1
Serum protein	5.8	7.1	6.7	6.4
(c.v.--%)	(2.3)	(6.5)	(9.3)	(7.7)
Eyes				
Normal(%)	100	100	100	100
Gills				
Normal(%)	100	100	100	100
Pseudobranchs				
Normal(%)	100	100	100	100
Thymus				
Normal(%)	100	75	80	70
Mild hemorrhage		25	20	30
Mesenteric fat				
None				
Little	65	35	5	40
Normal	35	65	45	60
Above normal			50	
Spleen				
Normal(%)	100	100	100	100
Hind gut				
Normal(%)	100	100	100	100
Kidney				
Normal(%)	100	100	100	100
Liver				
Normal(%)	90	100	100	100
Pale	10	-	-	-
Mesentery				
Normal(%)	100	100	100	100

Appendix 10. Summary of health indices of quadruple-density fish reared in pens using the Utah Fish Quality Indexing methodology, Drano Lake, 1987. (c.v. = coefficient of variation)

Observation	4/14	4/28	5/13	5/21
Fork Length(mm)	48.3	56.6	67.0	72.1
(c.v.--%)	(6.2)	(6.6)	(8.0)	(6.9)
Weight(g)	1.14	2.04	3.53	4.53
(c.v.--%)	(18.4)	(21.9)	(23.3)	(20.7)
Kfl	1.00	1.11	1.15	1.19
(c.v.--%)	(6.0)	(3.9)	(6.1)	(5.5)
Blood hematocrit	35.0	34.1	38.0	38.9
(c.v.--%)	(4.1)	(6.7)	(8.8)	(10.2)
Blood leucocrit	<1	<1	<1	<1
Serum protein	6.8	6.6	6.7	6.5
(c.v.--%)	(8.5)	(6.5)	(10.4)	(6.4)
Eyes				
Normal(%)	100	100	100	100
Gills				
Normal(%)	100	100	100	100
Pseudobranchs				
Normal(%)	100	100	100	100
Thymus				
Normal(%)	90	85	65	85
Mild hemorrhage	10	15	35	10
Severe hemorrhage	-	-		5
Mesenteric fat				
None	5	-		
Little	95	40	5	20
Normal	-	60	65	75
Above normal	-	-	30	5
Spleen				
Normal(%)	100	100	100	100
Hind gut				
Normal(%)	100	100	100	100
Kidney				
Normal(%)	100	100	100	100
Liver				
Normal(%)	100	100	100	100
Mesentery				
Normal(%)	100	100	100	100

Appendix 11. Summary of health indices of fish reared at the Little White Salmon National Fish Hatchery using the Utah Fish Quality Indexing methodology, 1987. (c.v. = coefficient of variation)

Observation	3/31	4/13	4/27	5/11
Fork Length(mm)	43.4	46.0	53.0	55.0
(c.v.--%)	(3.2)	(11.2)	(5.4)	(8.7)
Weight(g)	.75	1.02	1.53	1.76
(c.v.--%)	(10.9)	(20.3)	(15.6)	(26.8)
Kfl	1.09	1.00	1.03	1.02
(c.v.--%)	(5.1)	(6.98)	(5.6)	(6.7)
Blood hematocrit	33.4	37.0	37.0	38.0
(c.v.--%)	(5.9)	(3.7)	(5.7)	(9.8)
Blood leucocrit	<1	<1	<1	<1
Serum protein	5.8	6.4	7.0	6.8
(c.v.--%)	(9.2)	(2.9)	(7.7)	(7.3)
Eyes				
Normal(%)	100	100	100	100
Gills				
Normal(%)	100	100	100	100
Pseudobranchs				
Normal(%)	100	100	100	100
Thymus				
Normal(%)	100	100	90	95
Mild hemorrhage	-		10	5
Mesenteric fat				
None	-	10	-	5
Little	100	90	100	90
Normal	-		-	5
Above normal	-		-	-
Spleen				
Normal(%)	100	100	100	100
Hind gut				
Normal(%)	100	100	100	100
Kidney				
Normal(%)	100	100	100	100
Liver				
Normal(%)	-	35	100	100
Pale	100	65	-	-
Mesentery				
Normal(%)	100	100	100	100

Appendix 12. Summary of health indices of unfed fish reared in pens using the Utah Fish Quality Indexing methodology, Drano Lake, 1987. (c.v. = coefficient of variation)

Observation	4/23a	5/6a	5/19			6/3		
	Composite	Composite	Lo	Med	Hi	Lo	Med	Hi
Fork Length(mm)	47.9	48.0	49.0	48.0	48.0	52.1	47.7	49.5
(c.v.--%)	(7.3)	(4.0)	(4.4)	(4.4)	(4.2)	(6.9)	(4.4)	(5.9)
Weight(g)	.96	.89	.99	.87	.76	1.27	.80	.82
(c.v.--%)	(21.4)	(14.0)	(14.4)	(15.2)	(15.3	(30.9)	(20.2)	(19.8)
Kfl	.88	.80	.84	.76	.67	.88	.73	.67
(c.v.--%)	(9.7)	(5.8)	(6.9)	(8.6)	(7.3)	(11.8)	(9.4)	(9.0)
Blood hematocrit	41.2	39.7	38.0	37.0	36.0	38.6	35.3	33.5
(c.v.--%)	(6.1)	(7.7)	(7.6)	(6.8)	(4.4)	(11.9)	(7.8)	(6.3)
Blood leucocrit	<1	<1	<1	<1	<1	<1	<1	<1
Serum protein	5.1	3.8	3.9	3.4	2.4	4.2	2.4	1.7
(c.v.--%)	(3.2)	(12.8)	(15.3)	(12.4)	(11.6)	(22.5)	(19.5)	(8.7)
Eyes								
Normal(%)	100	100	100	100	100	100	100	100
Gills								
Normal(%)	100	100	100	100	100	100	100	100
Pseudobranchs								
Normal(%)	100	100	100	100	100	100	100	100
Thymus								
Normal(%)	95	100	100	100	100	100	100	100
Mild hemorrhage	5	-	-	-				
Mesenteric fat								
None	70	100	100	100	100	100	100	100
Little	30	-	-	-	-	-	-	-
Normal	-	-	-	-	-	-	-	-
Above normal	-	-	-	-	-	-	-	-
Spleen								
Normal(%)	100	100	95	95	100	100	100	100
Nodules	-	-	5	5				
Hind gut								
Normal(%)	100	100	100	100	100	100	100	100
Kidney								
Normal(%)	100	100	100	100	100	100	100	100
Liver								
Normal(%)	100	100	100	100	100	100	100	100
Pale	-	-	-	-				
Mesentery								
Normal(%)	100	100	100	100	100	100	100	100

SUMMARY OF DIRECT COSTS, FY 87

Salaries and Benefits	$ 154,083
Travel and Transportation	26,142
Equipment	
Non-expendable	0
Expendable	24,175
Operation and Maintenance	5,000
Total	$ 209,400